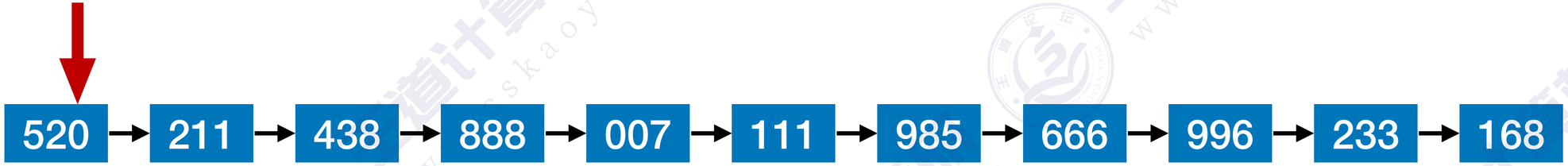
本节内容

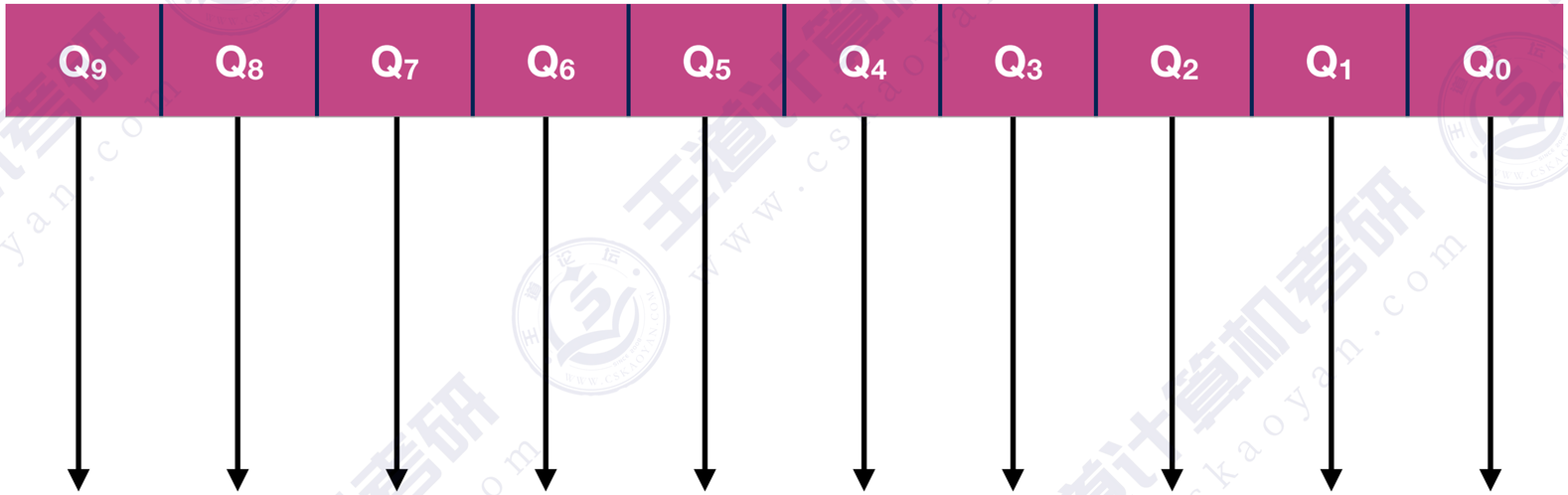
基数排序

(Radix Sort)

基数排序

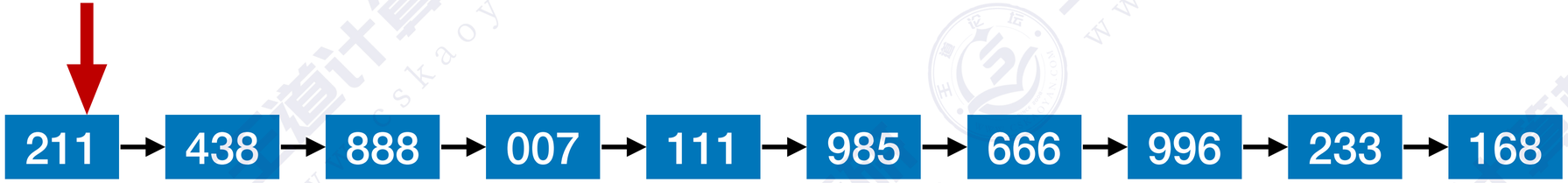


第一趟：以“个位”进行“分配”

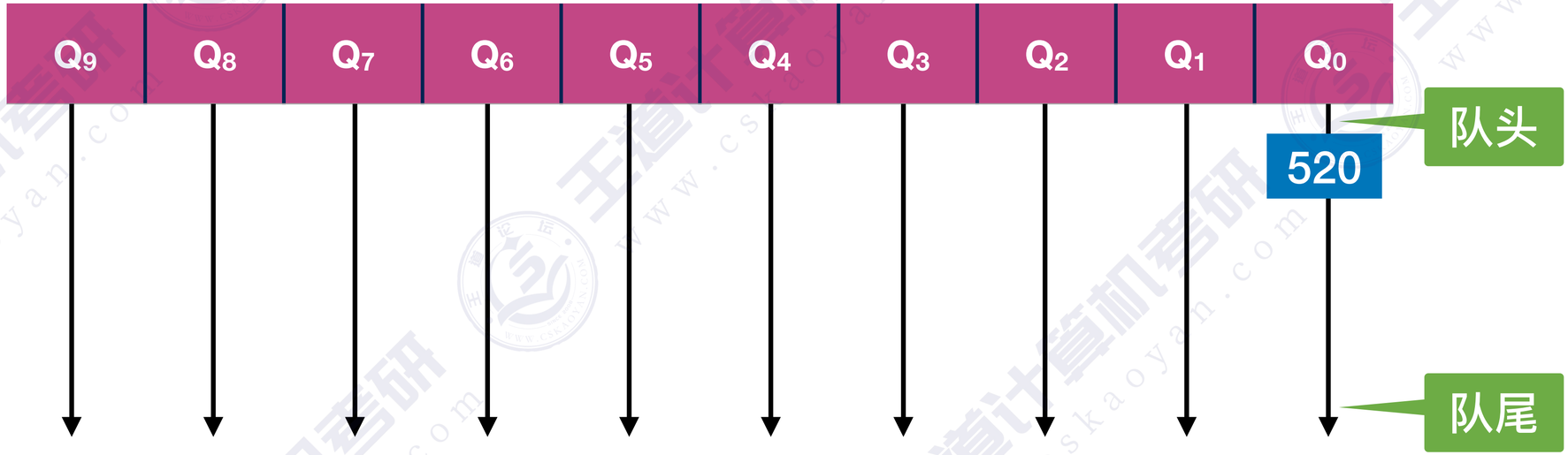


要求：得到按关键字“递减”的有序序列。

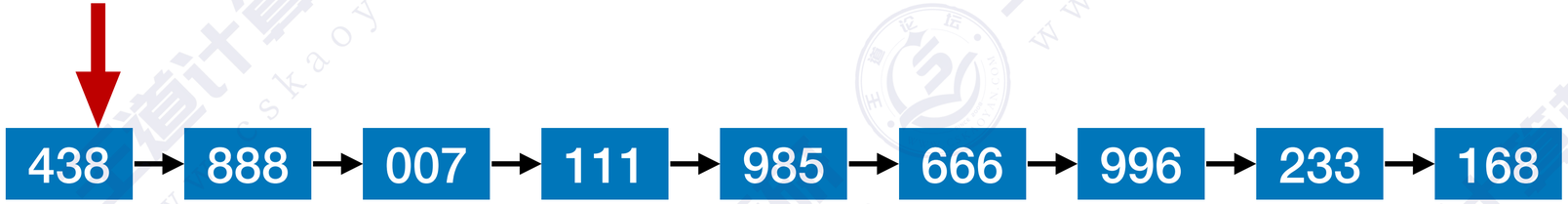
基数排序



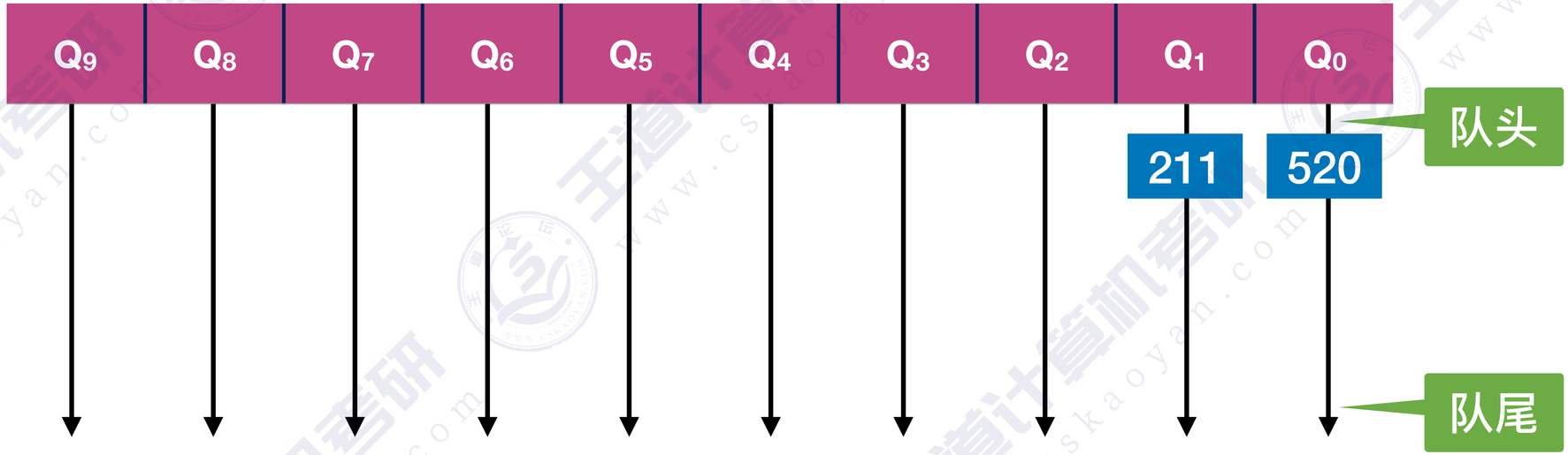
第一趟：以“个位”进行“分配”



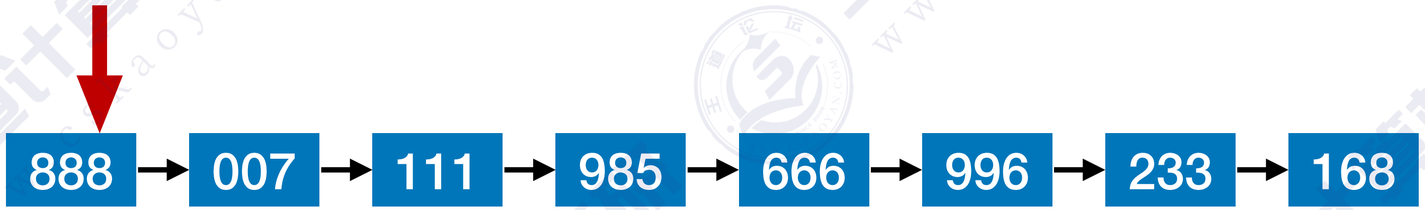
基数排序



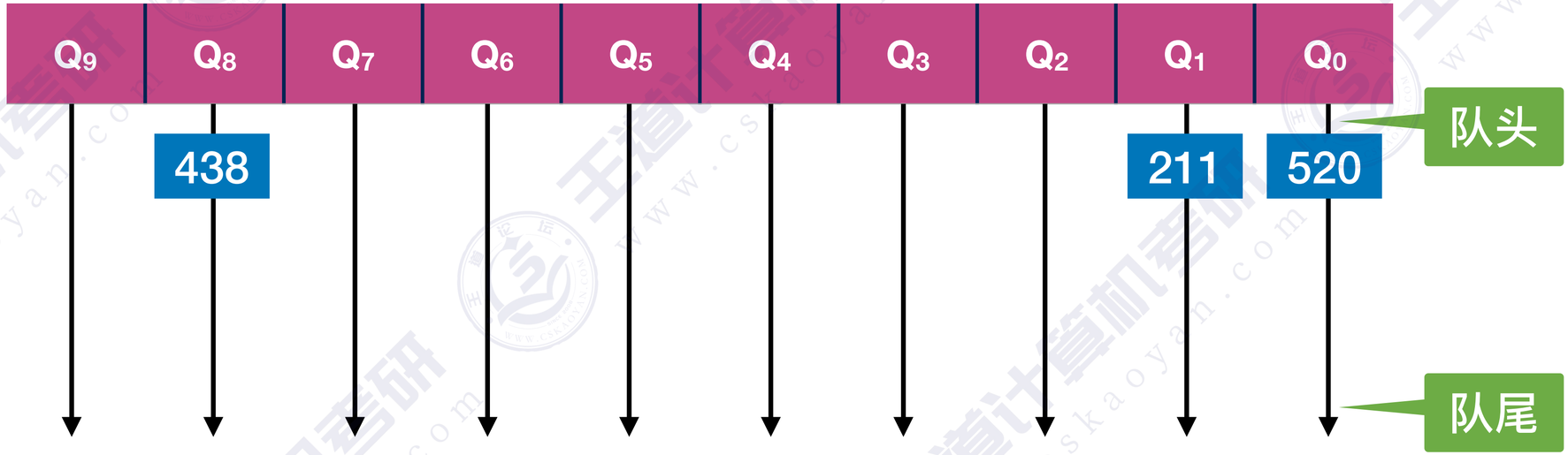
第一趟：以“个位”进行“分配”



基数排序

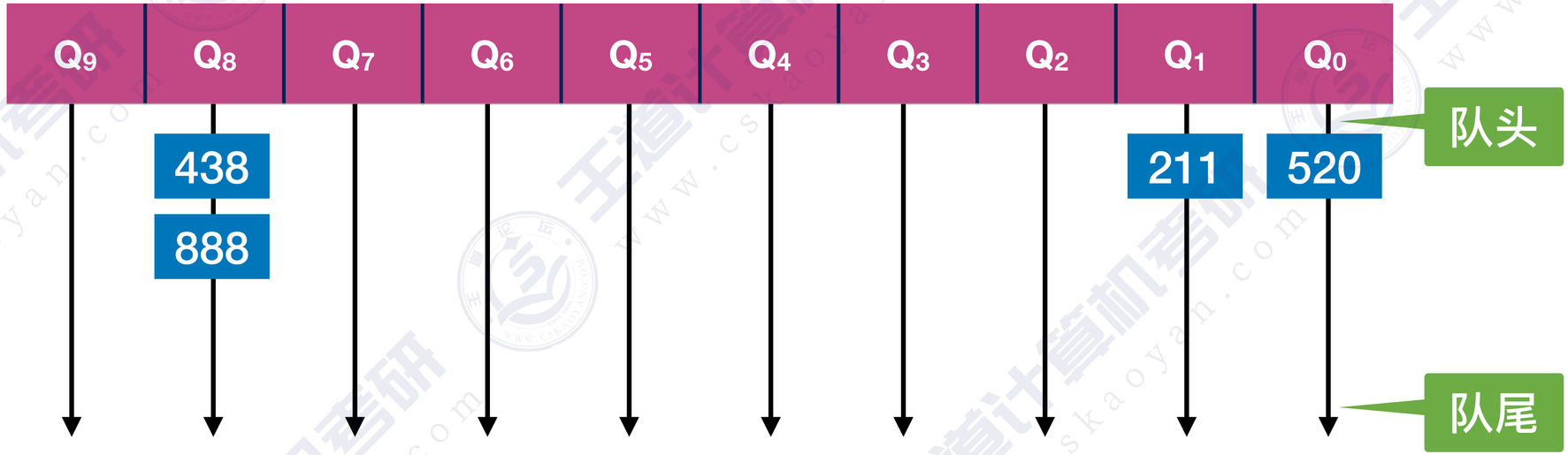


第一趟：以“个位”进行“分配”

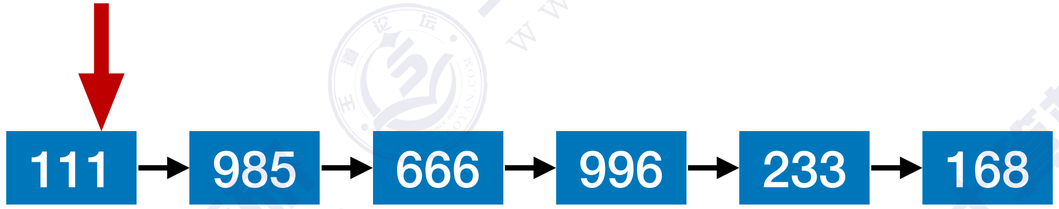


基数排序

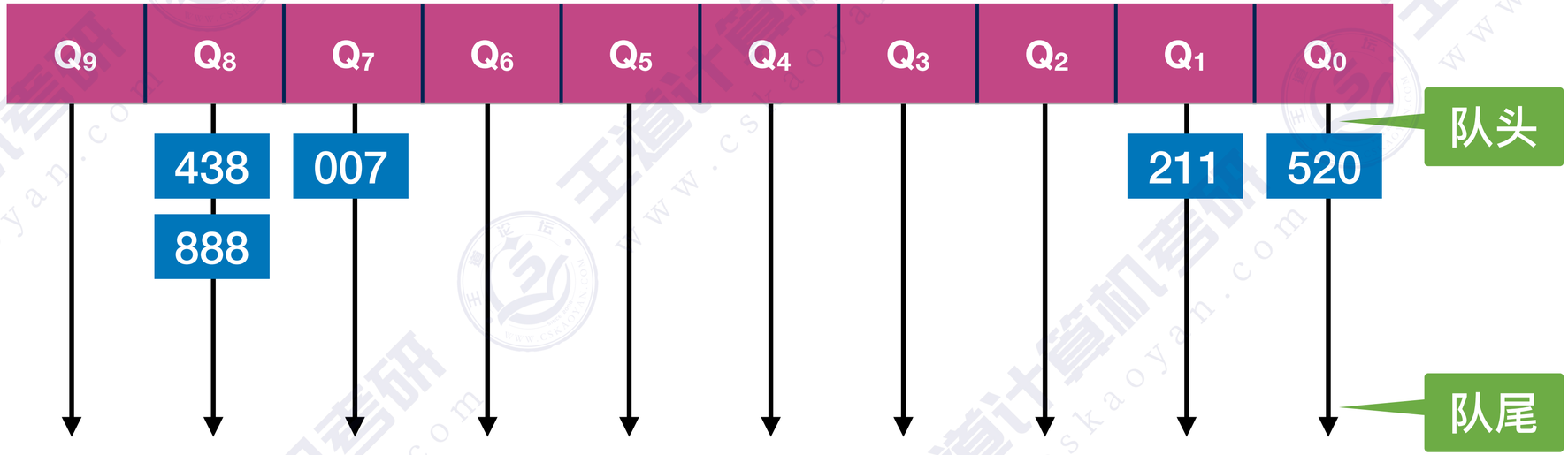
第一趟：以“个位”进行“分配”



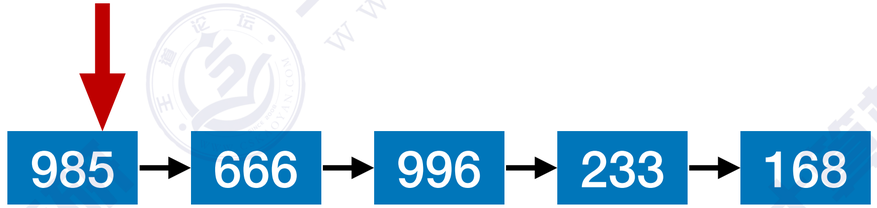
基数排序



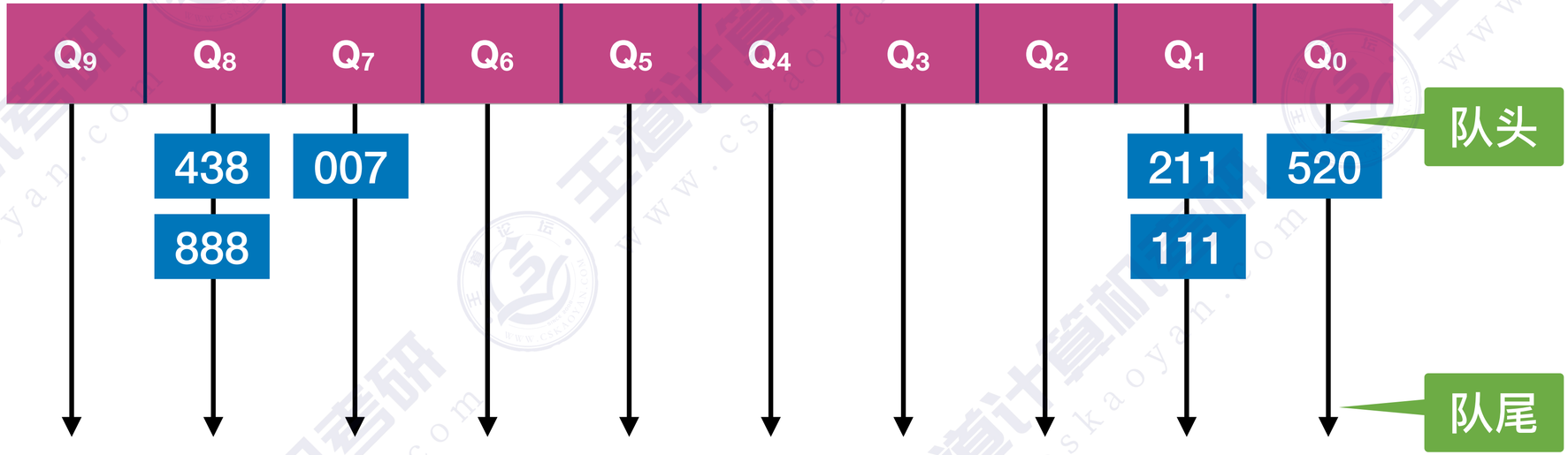
第一趟：以“个位”进行“分配”



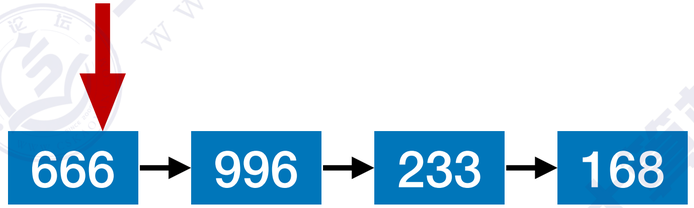
基数排序



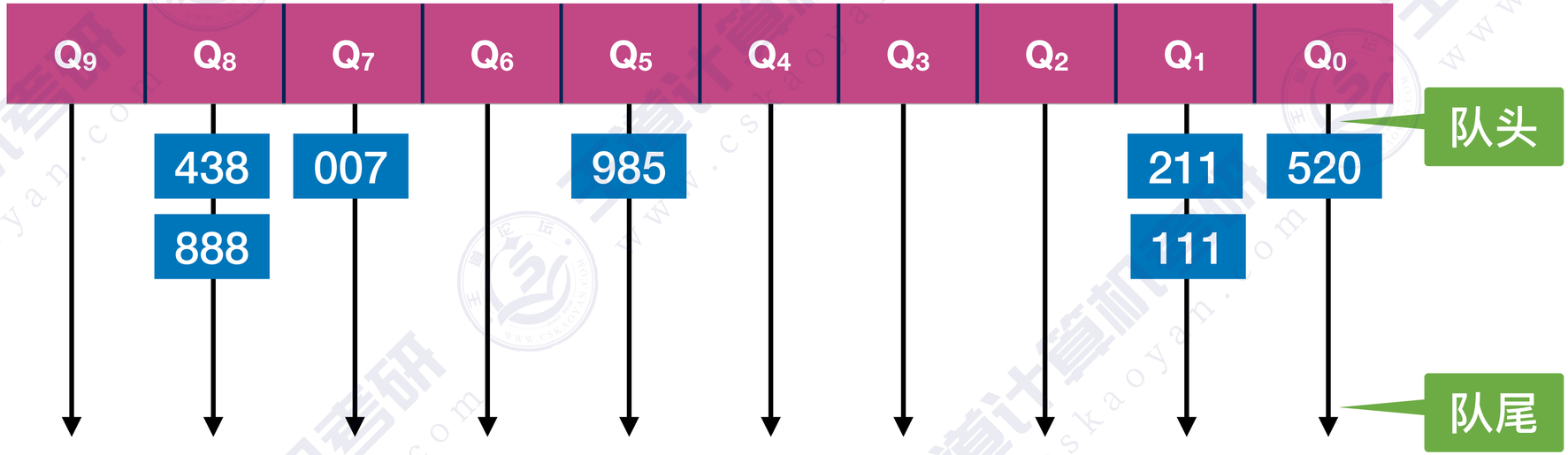
第一趟：以“个位”进行“分配”



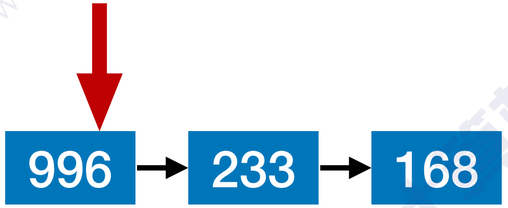
基数排序



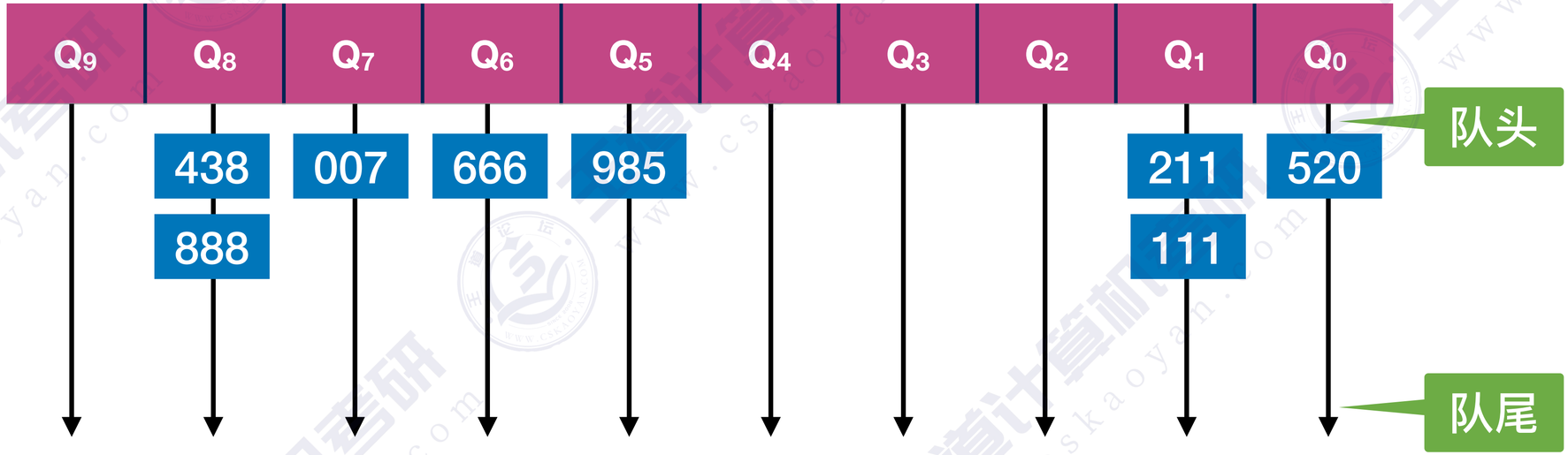
第一趟：以“个位”进行“分配”



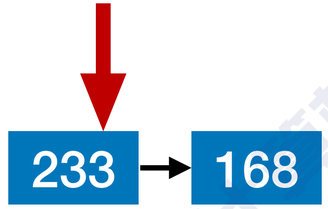
基数排序



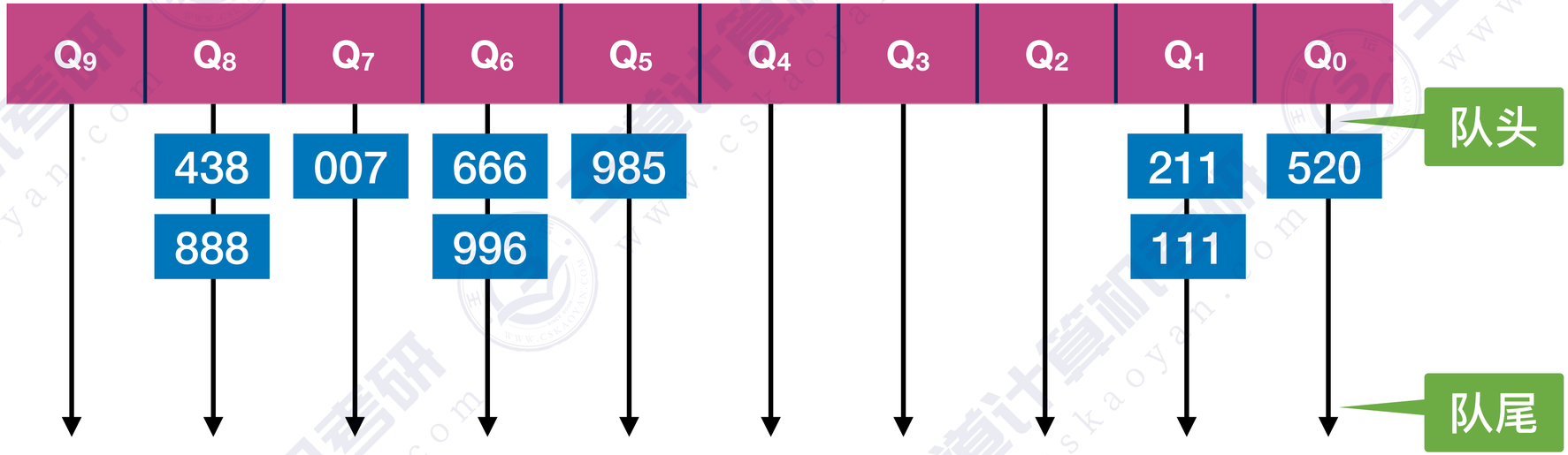
第一趟：以“个位”进行“分配”



基数排序



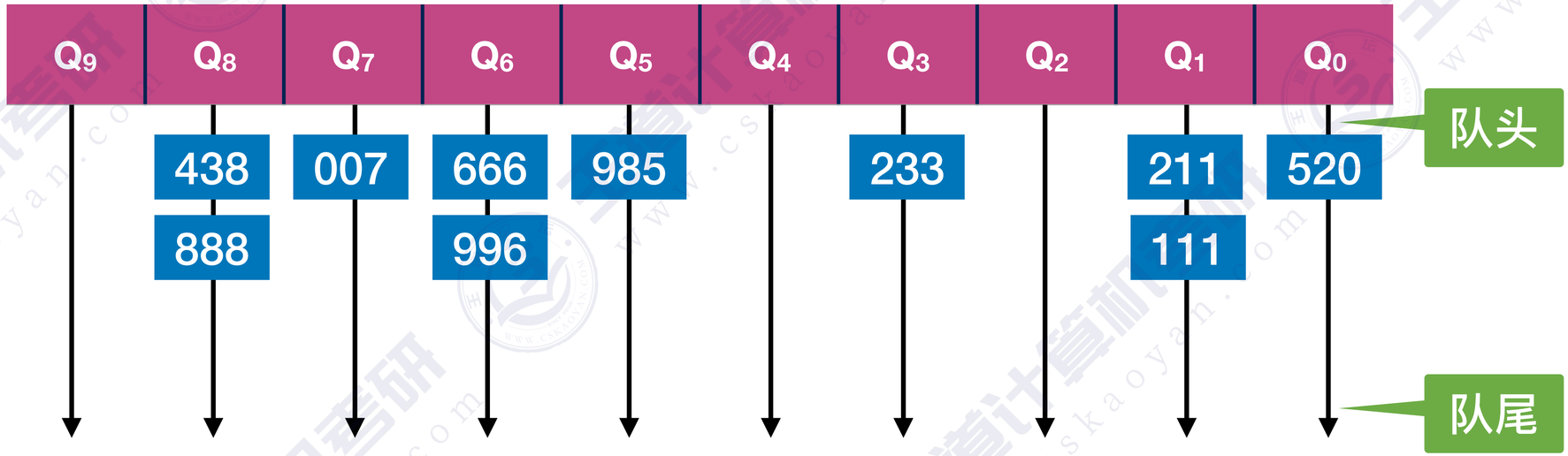
第一趟：以“个位”进行“分配”



基数排序

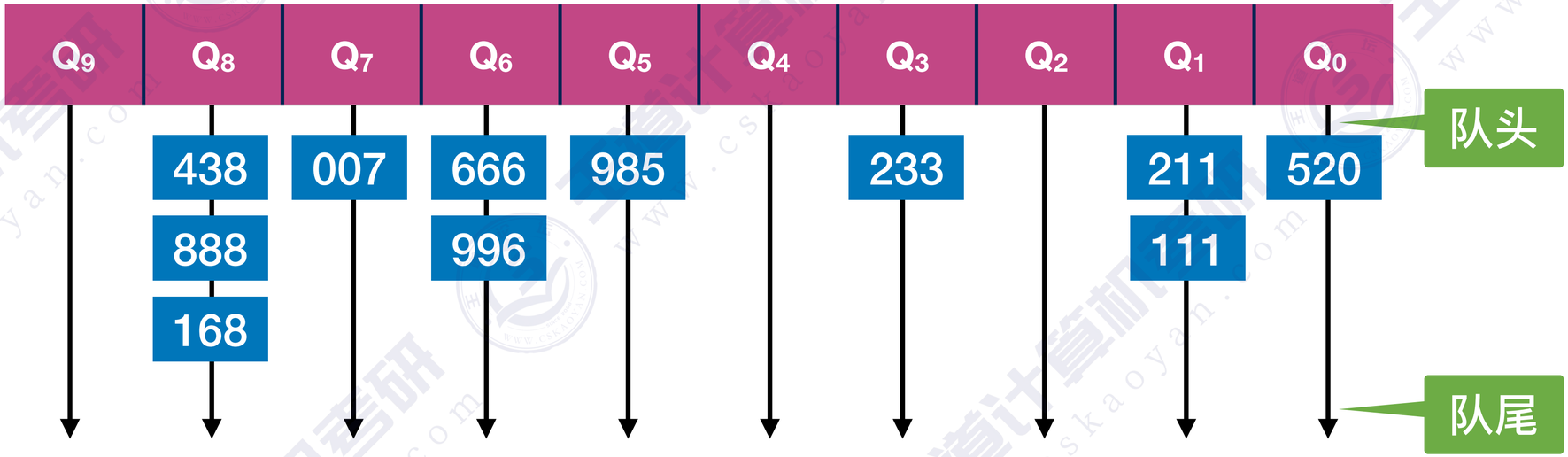
168

第一趟：以“个位”进行“分配”

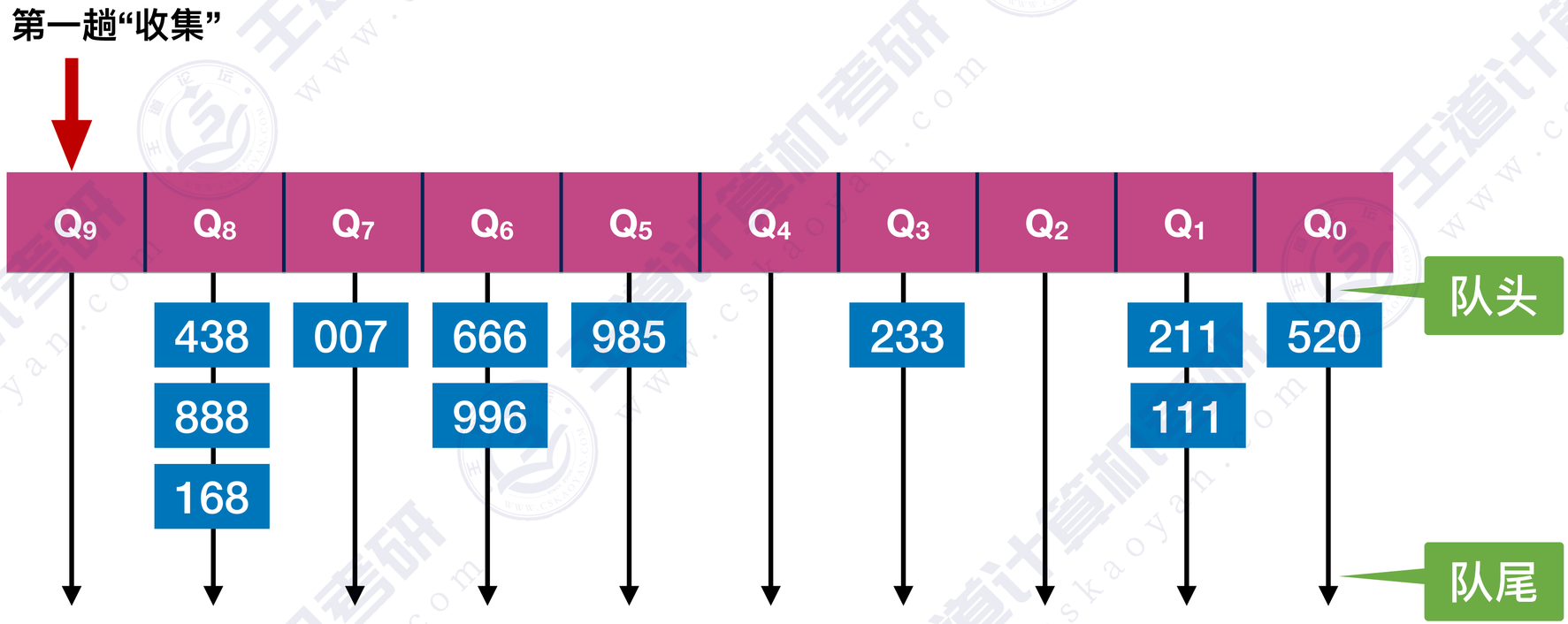


基数排序

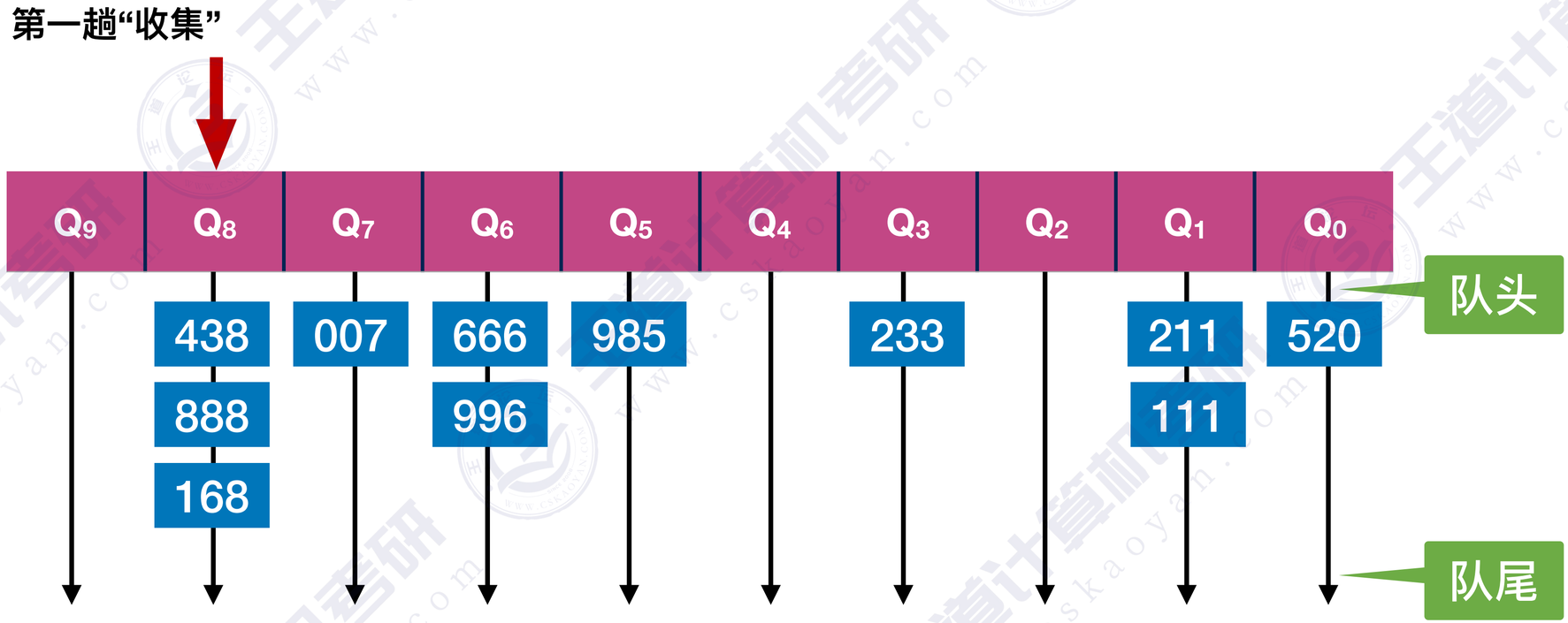
第一趟“分配”结束



基数排序

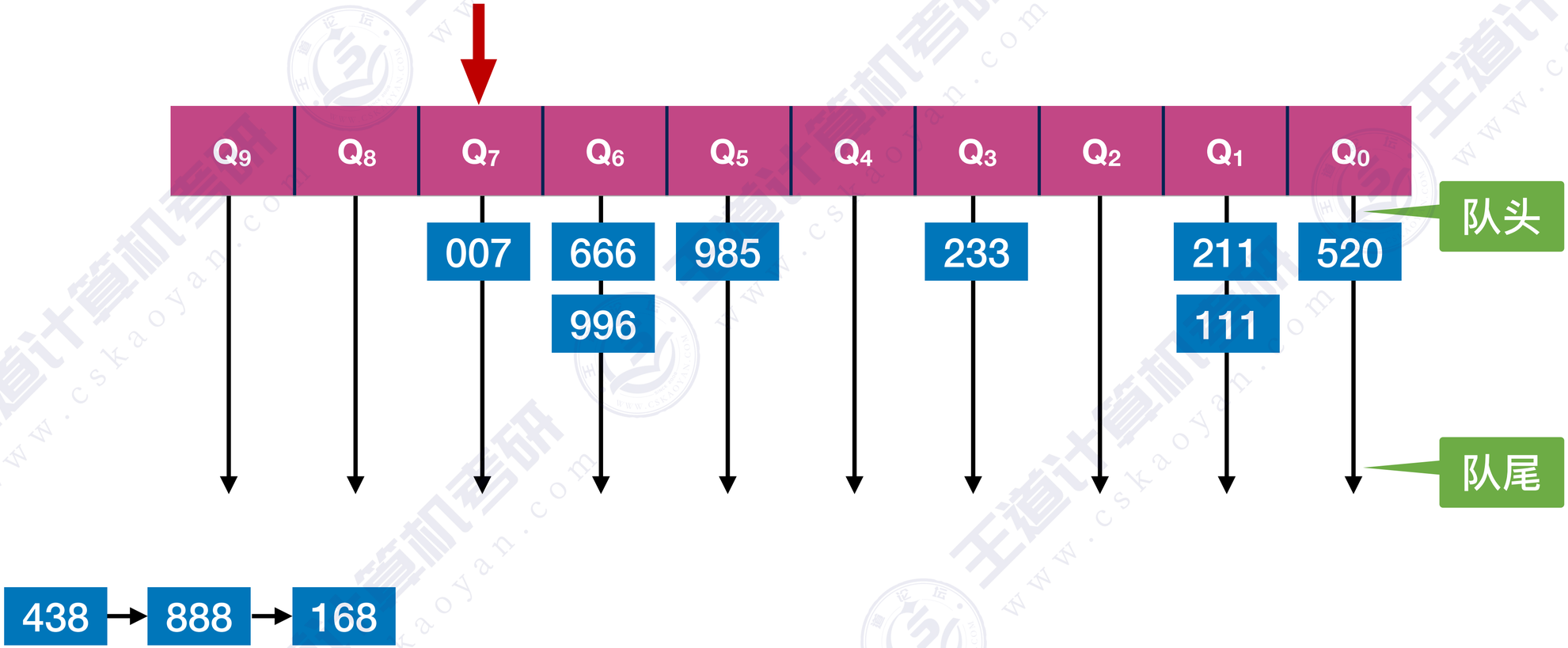


基数排序



基数排序

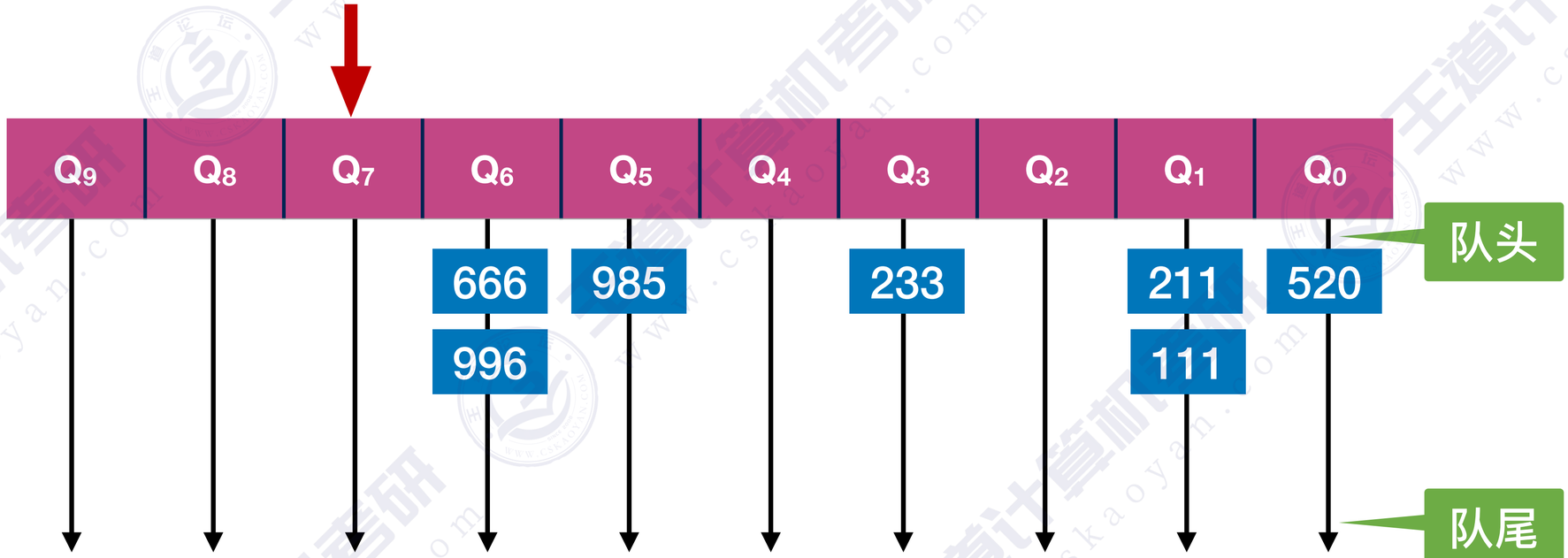
第一趟“收集”



438 → 888 → 168

基数排序

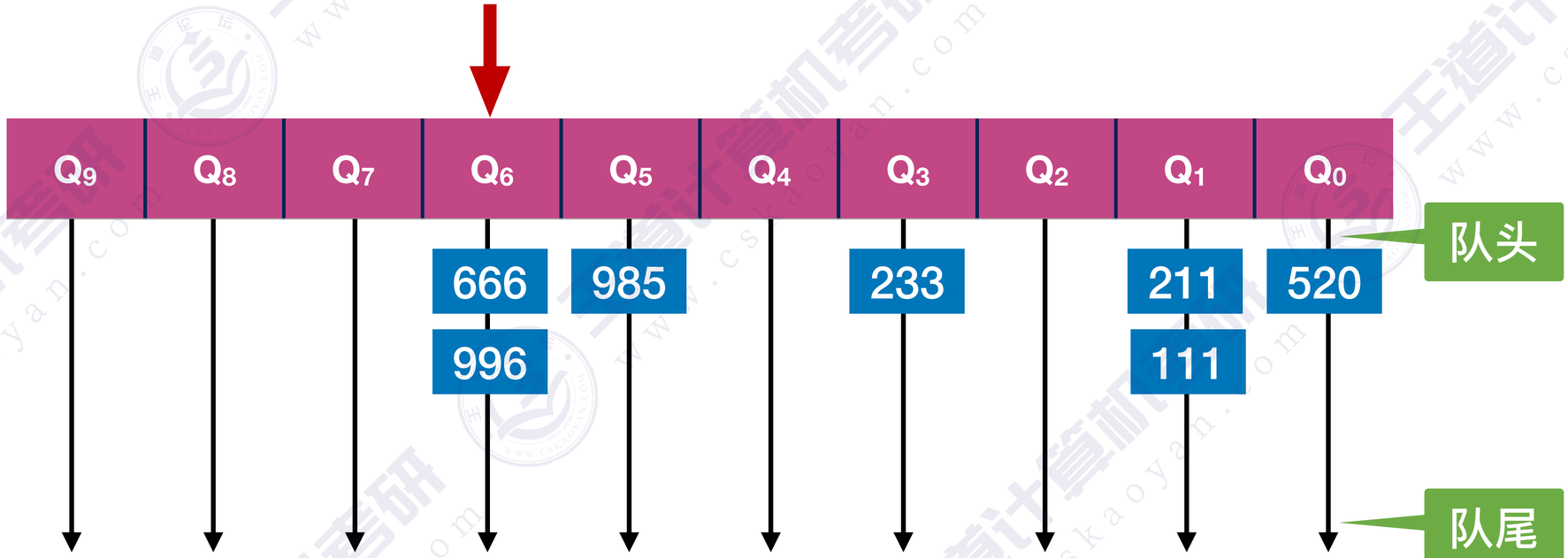
第一趟“收集”



438 → 888 → 168 → 007

基数排序

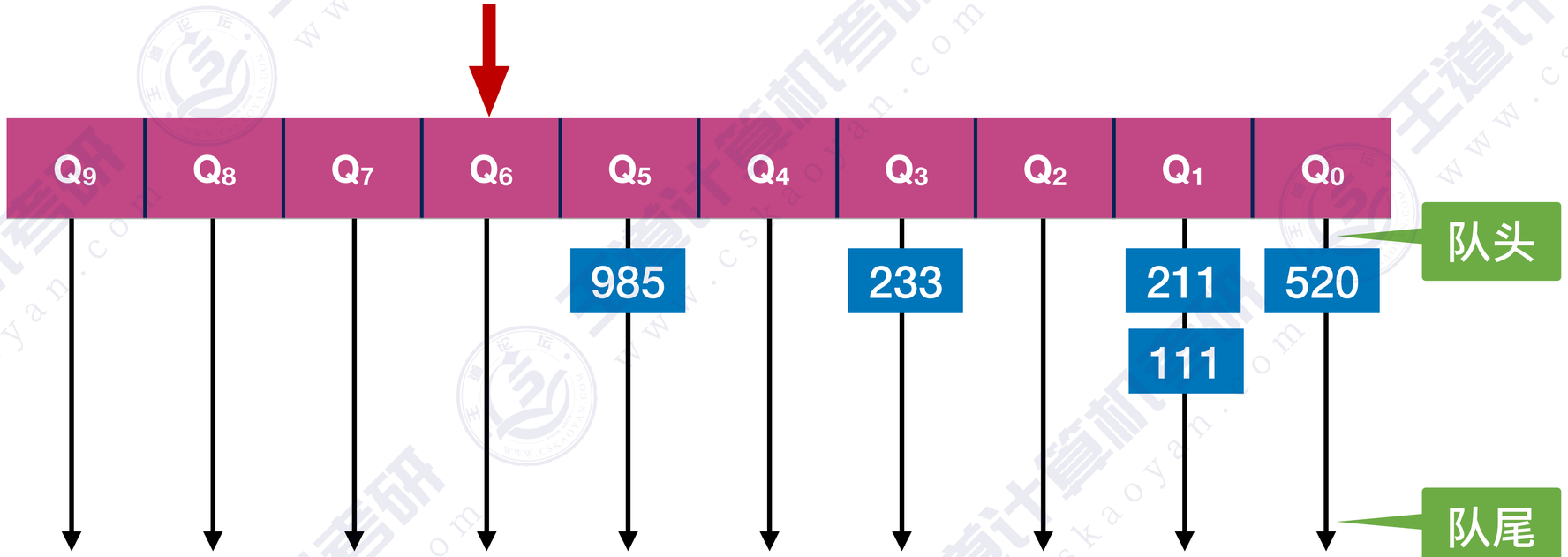
第一趟“收集”



438 → 888 → 168 → 007

基数排序

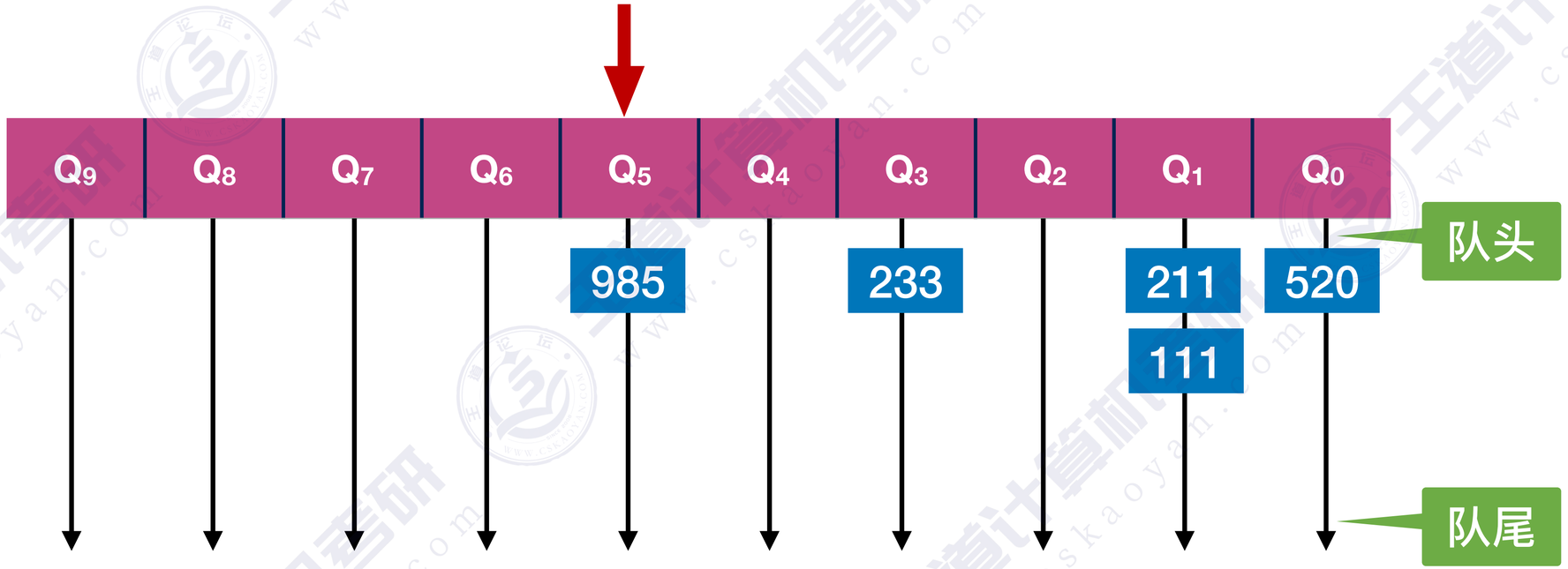
第一趟“收集”



438 → 888 → 168 → 007 → 666 → 996

基数排序

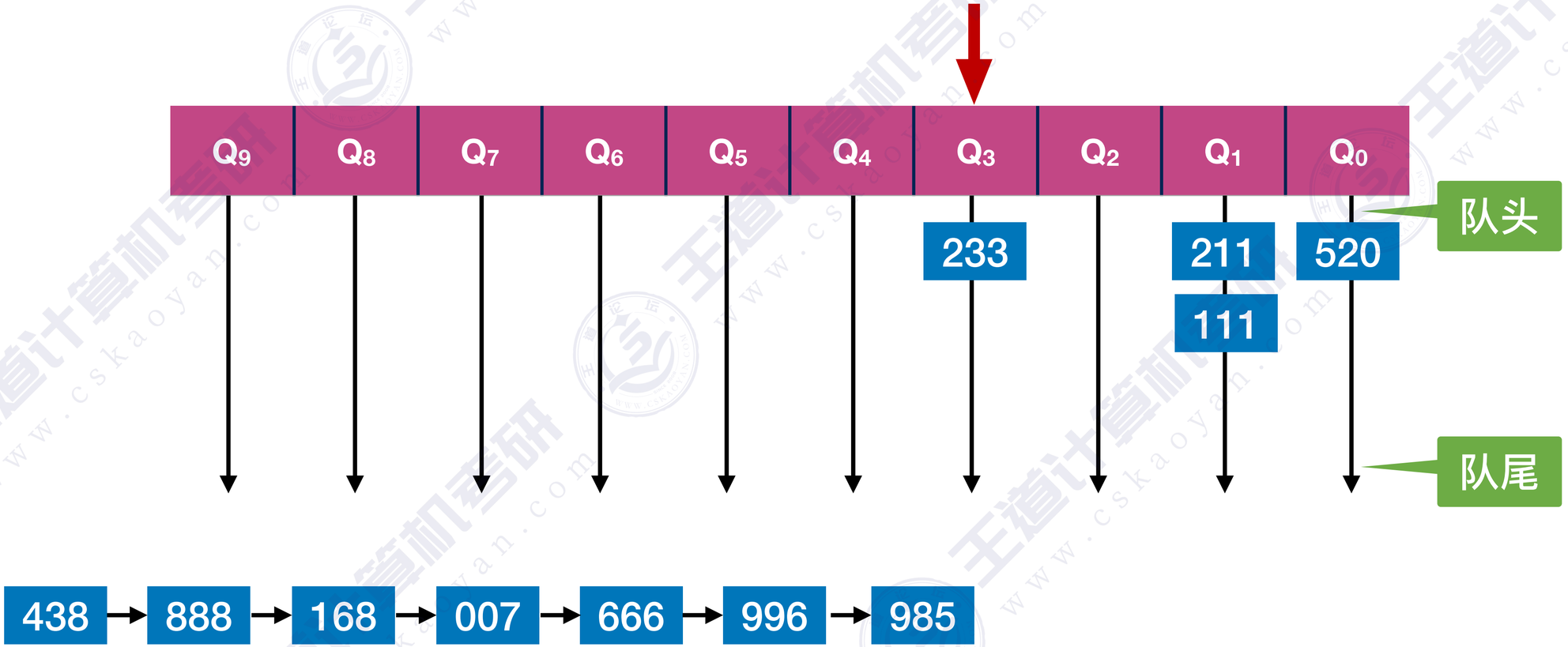
第一趟“收集”



438 → 888 → 168 → 007 → 666 → 996

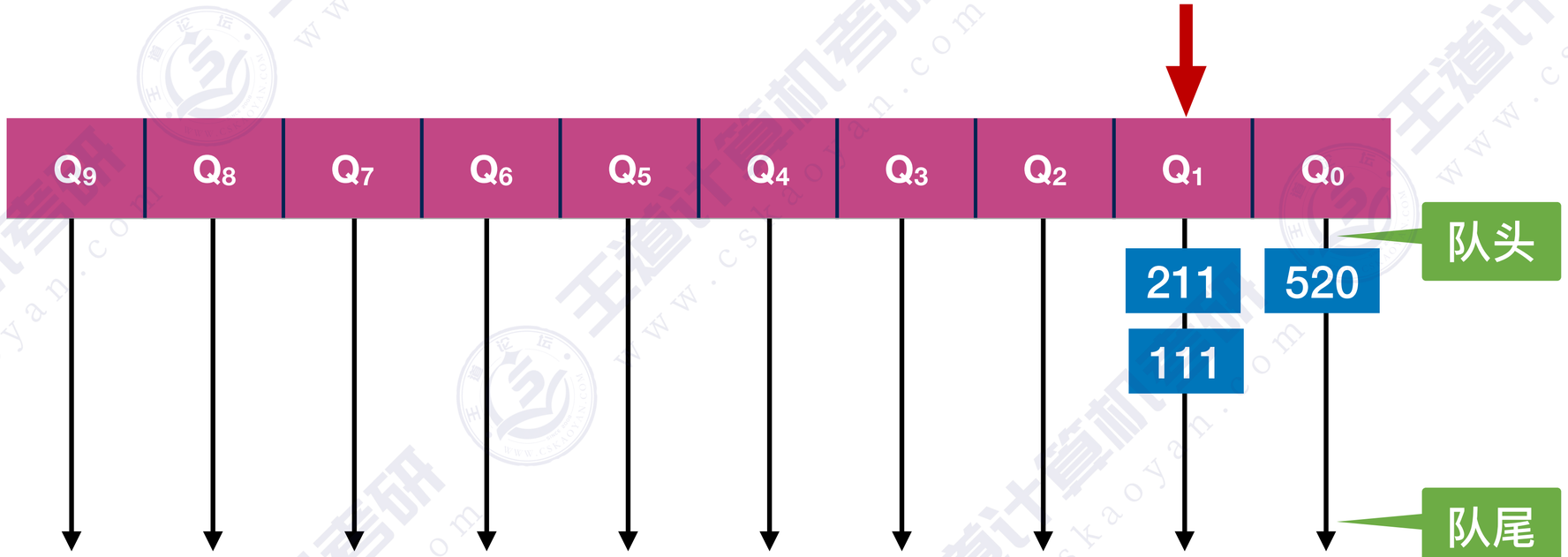
基数排序

第一趟“收集”



基数排序

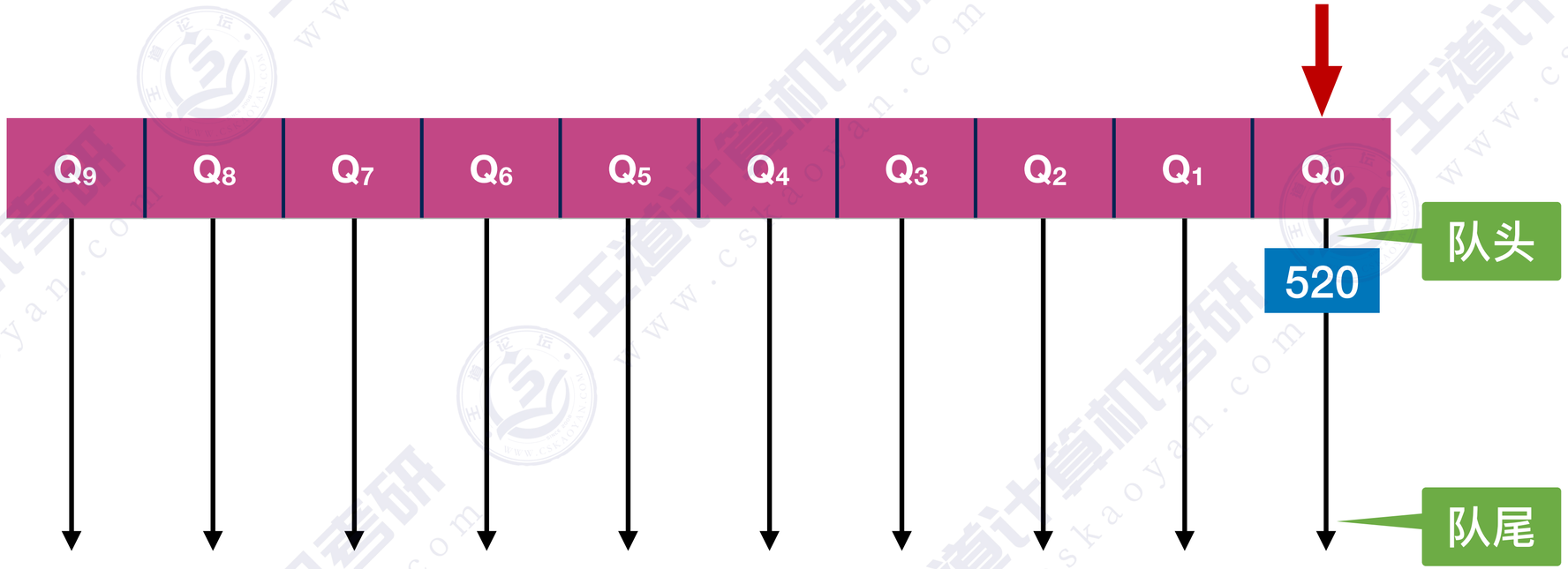
第一趟“收集”



438 → 888 → 168 → 007 → 666 → 996 → 985 → 233

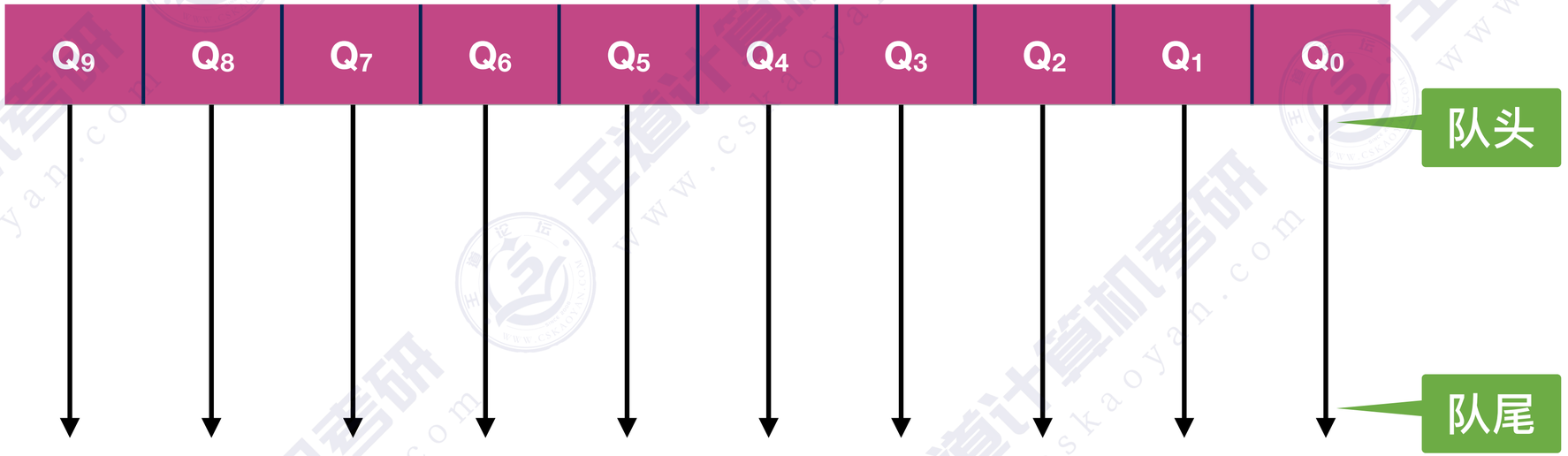
基数排序

第一趟“收集”



438 → 888 → 168 → 007 → 666 → 996 → 985 → 233 → 211 → 111

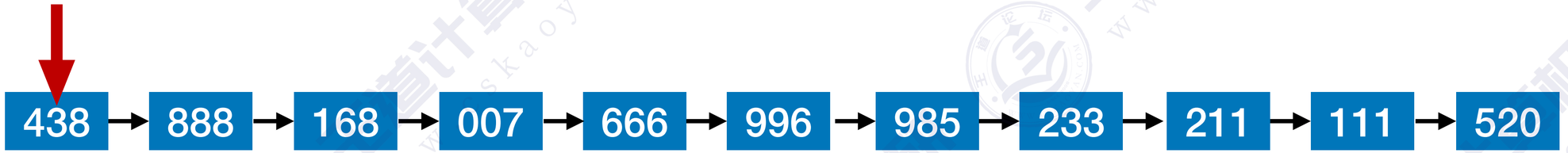
基数排序



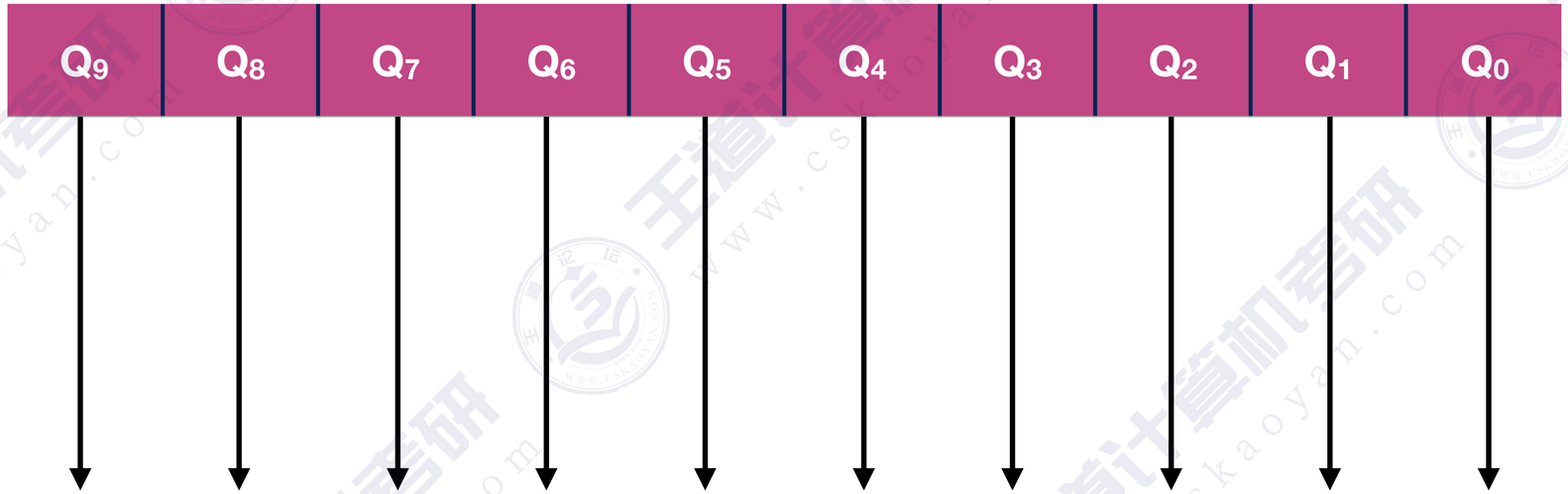
第一趟“收集”结束：得到按“个位”递减排序的序列

438 → 888 → 168 → 007 → 666 → 996 → 985 → 233 → 211 → 111 → 520

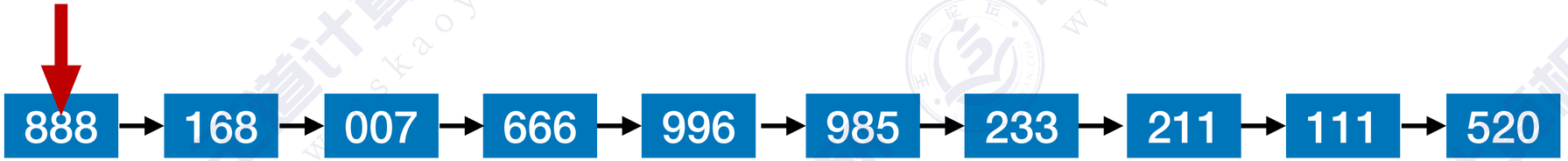
基数排序



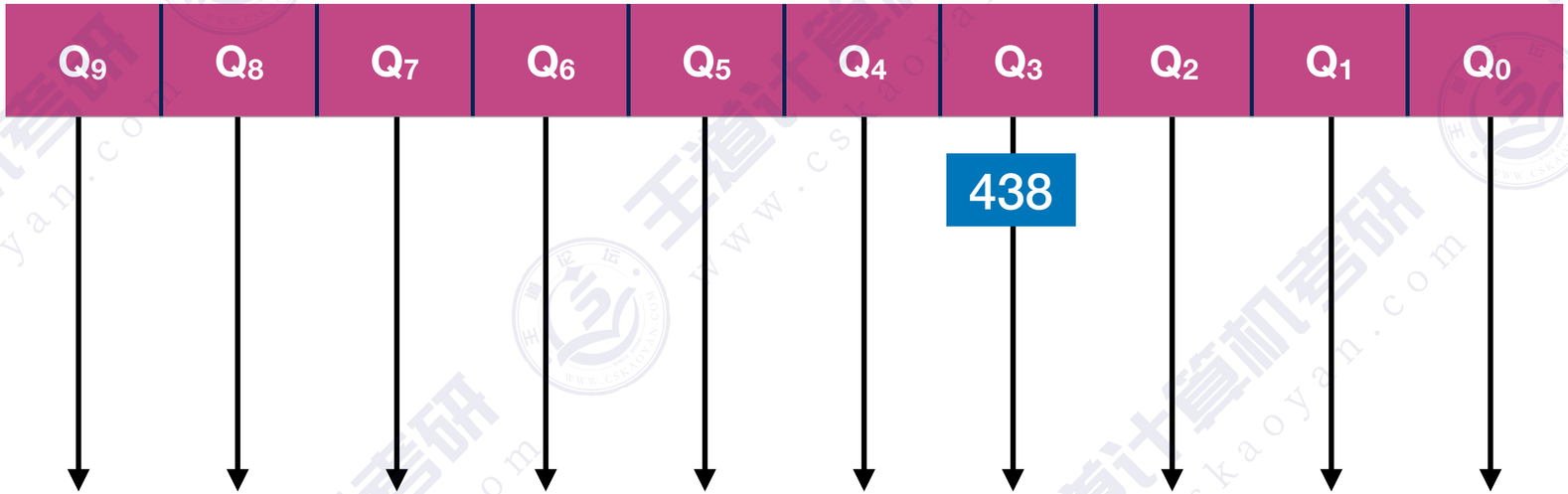
第二趟：以“十位”进行“分配”



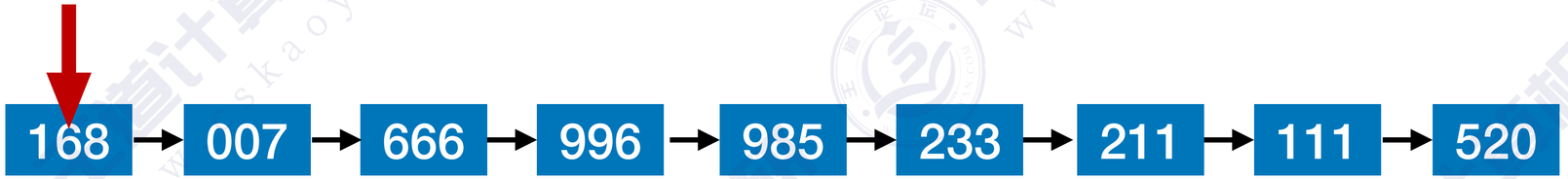
基数排序



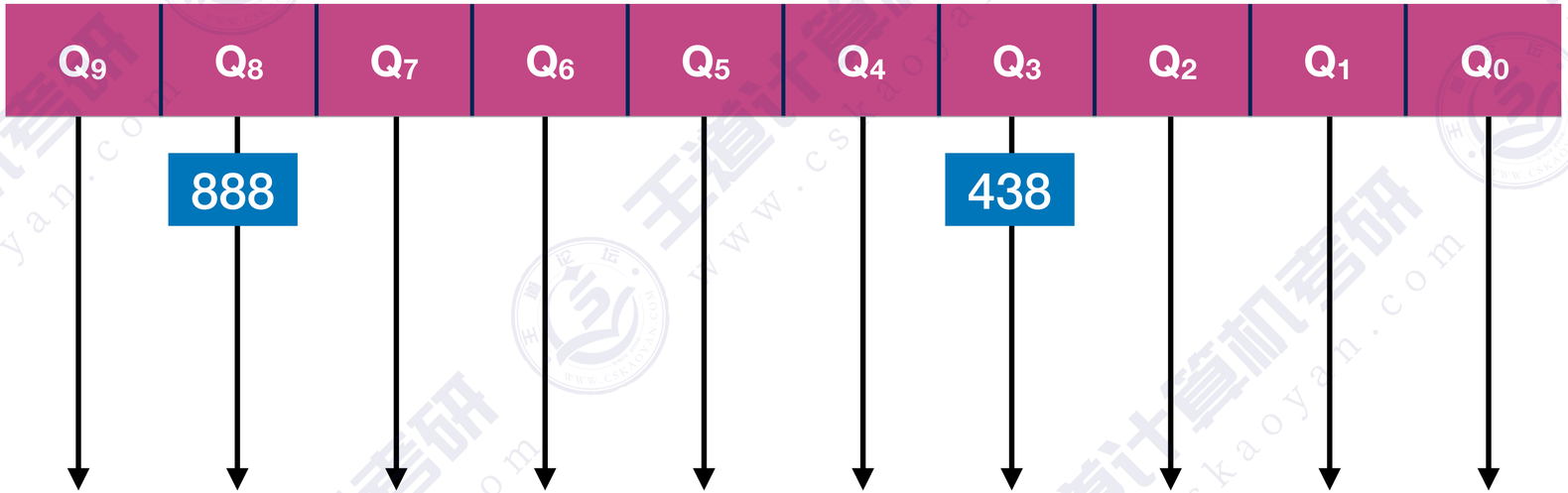
第二趟：以“十位”进行“分配”



基数排序

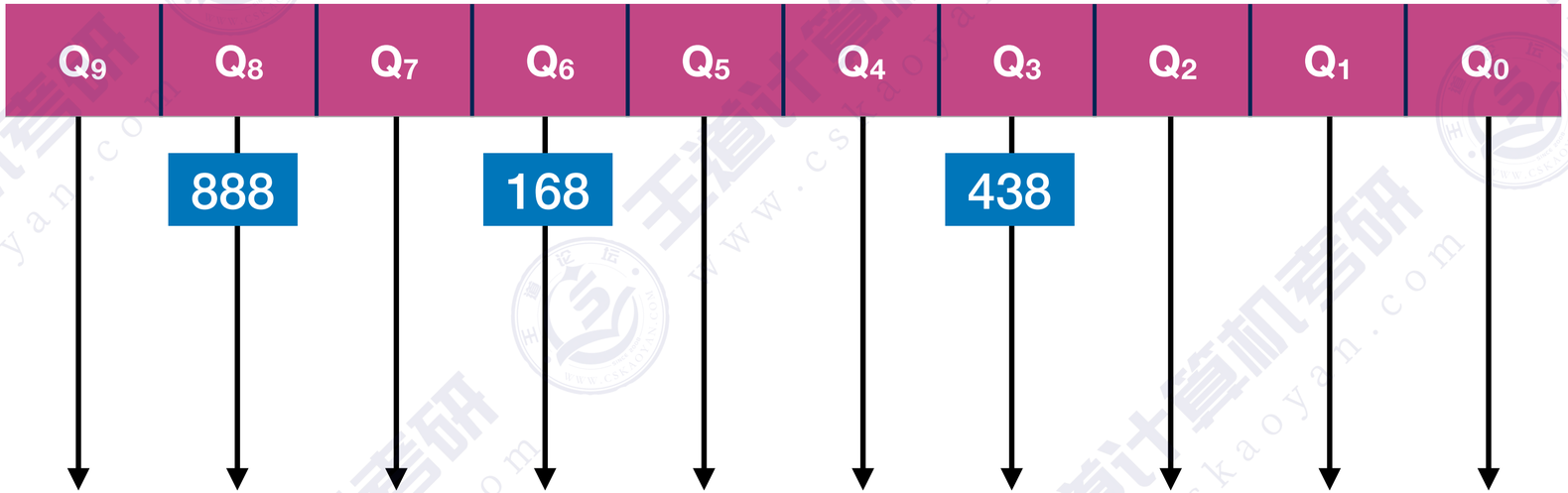


第二趟：以“十位”进行“分配”



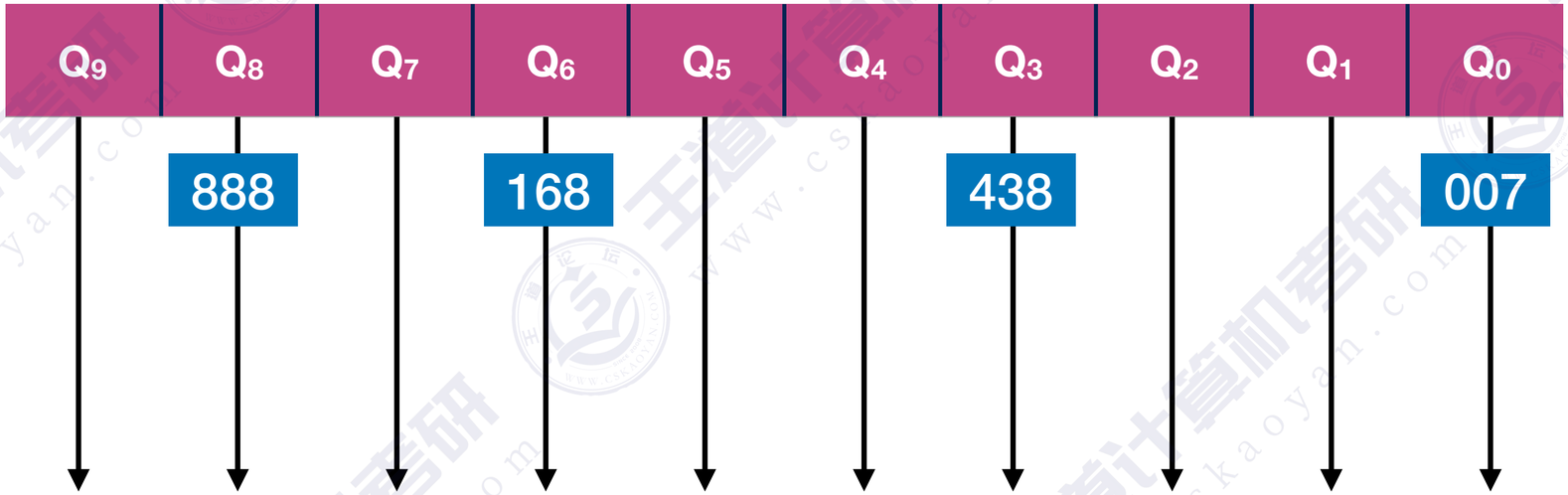
基数排序

第二趟：以“十位”进行“分配”

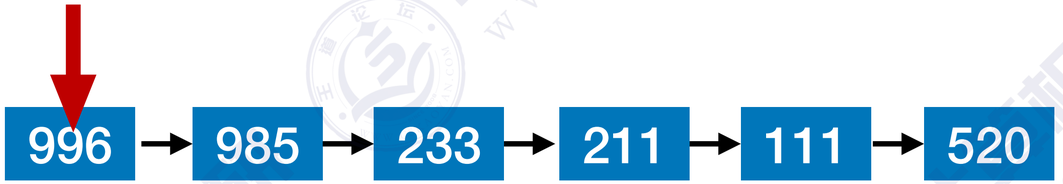


基数排序

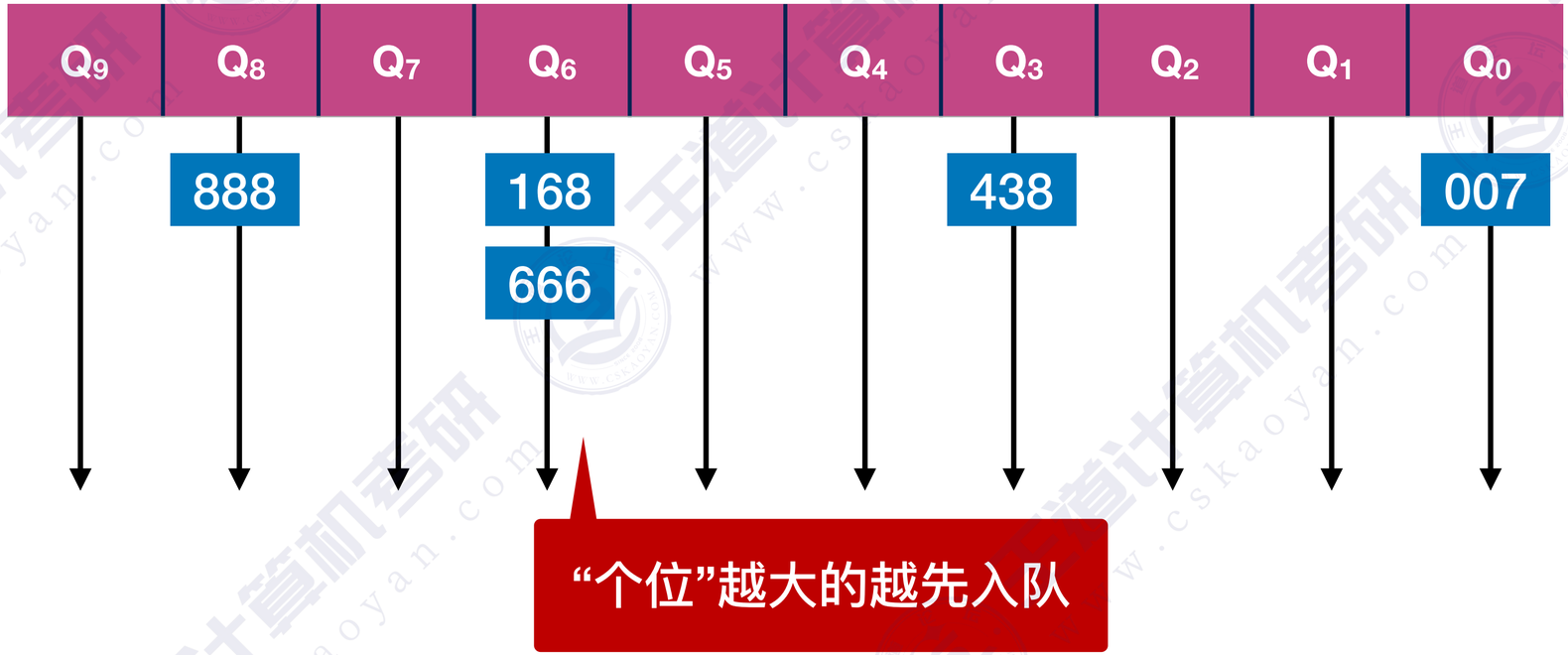
第二趟：以“十位”进行“分配”



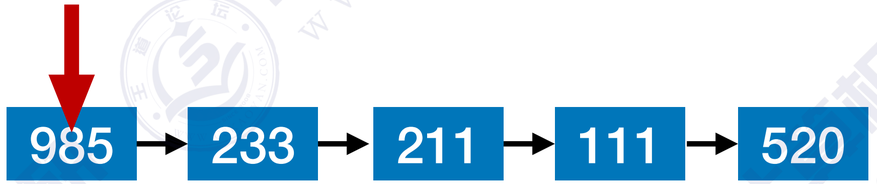
基数排序



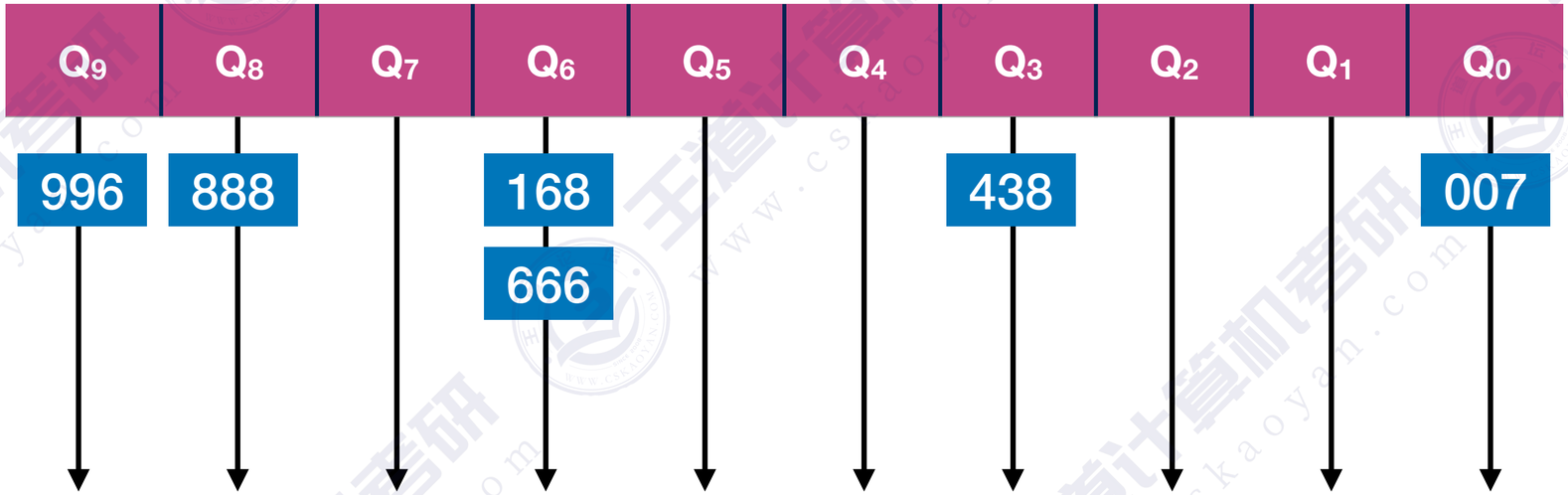
第二趟：以“十位”进行“分配”



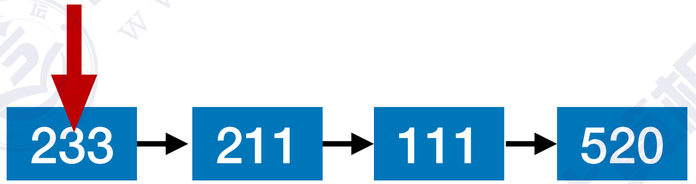
基数排序



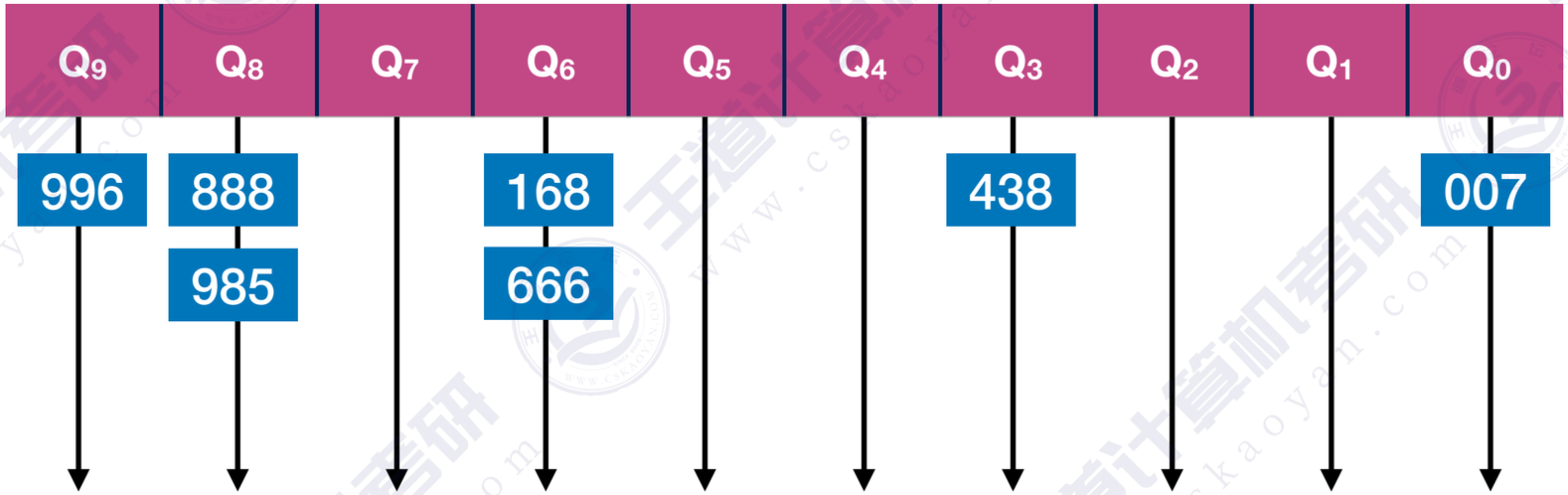
第二趟：以“十位”进行“分配”



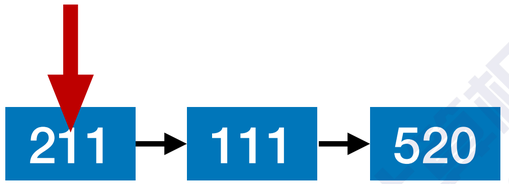
基数排序



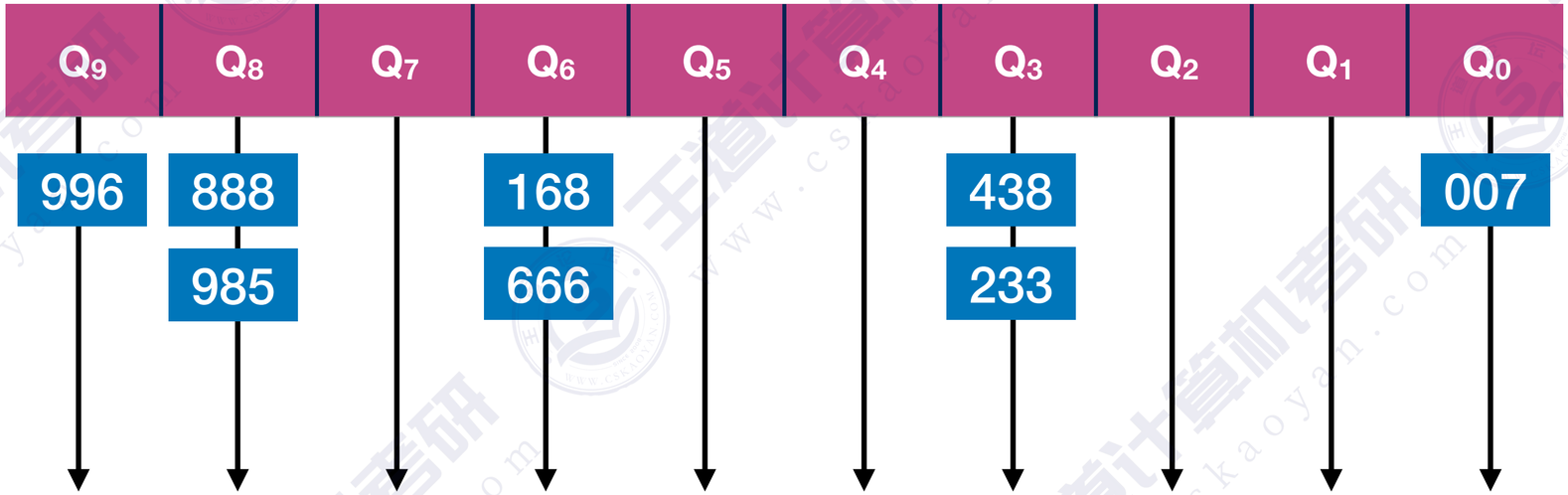
第二趟：以“十位”进行“分配”



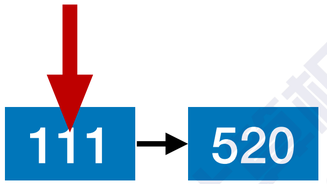
基数排序



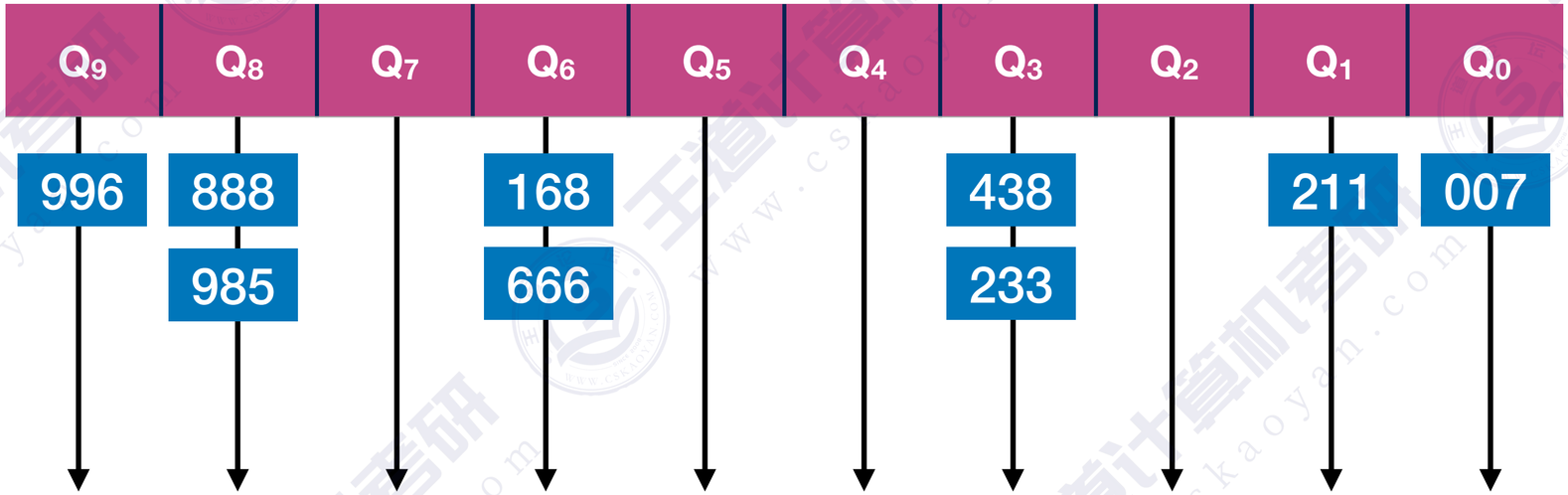
第二趟：以“十位”进行“分配”



基数排序

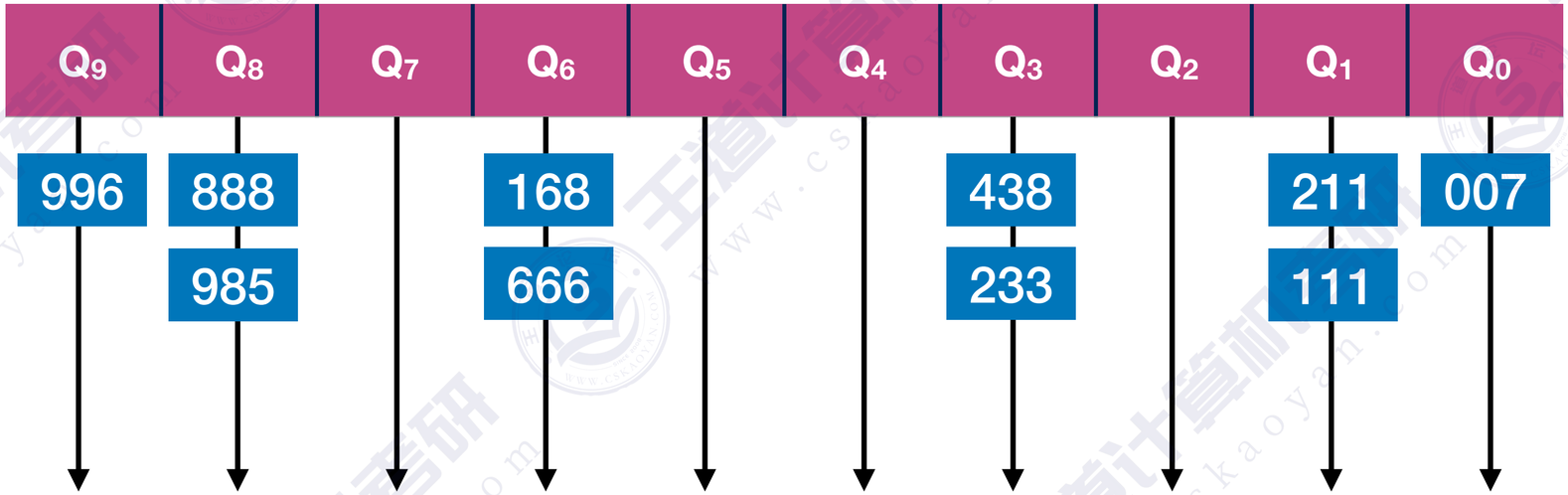


第二趟：以“十位”进行“分配”



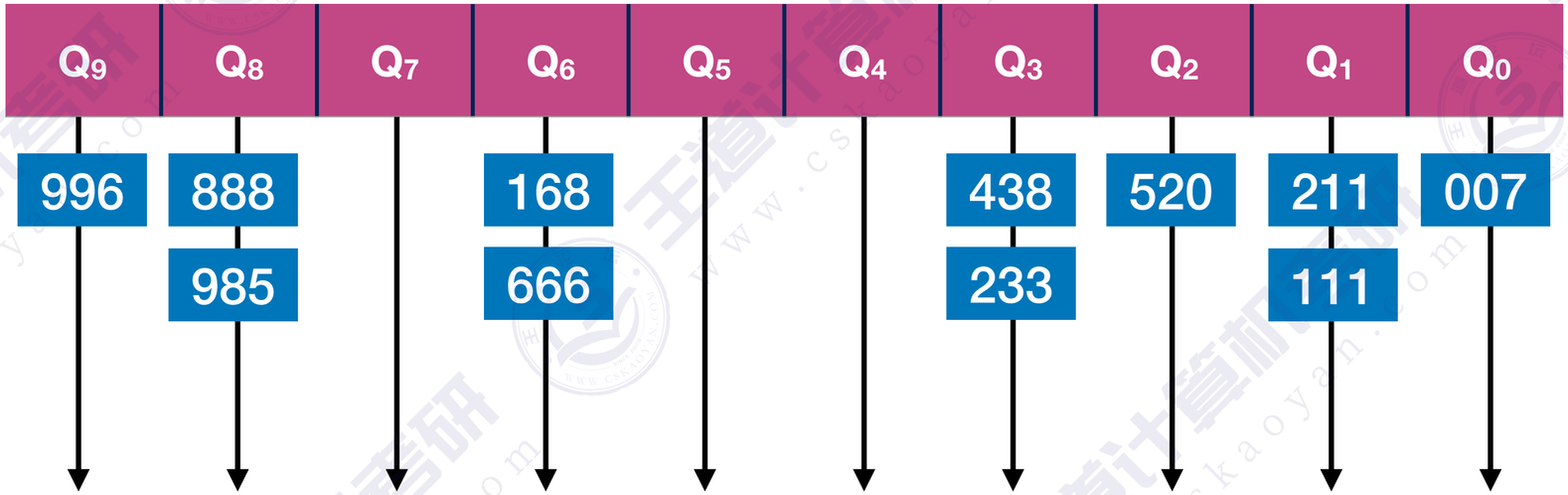
基数排序

第二趟：以“十位”进行“分配”



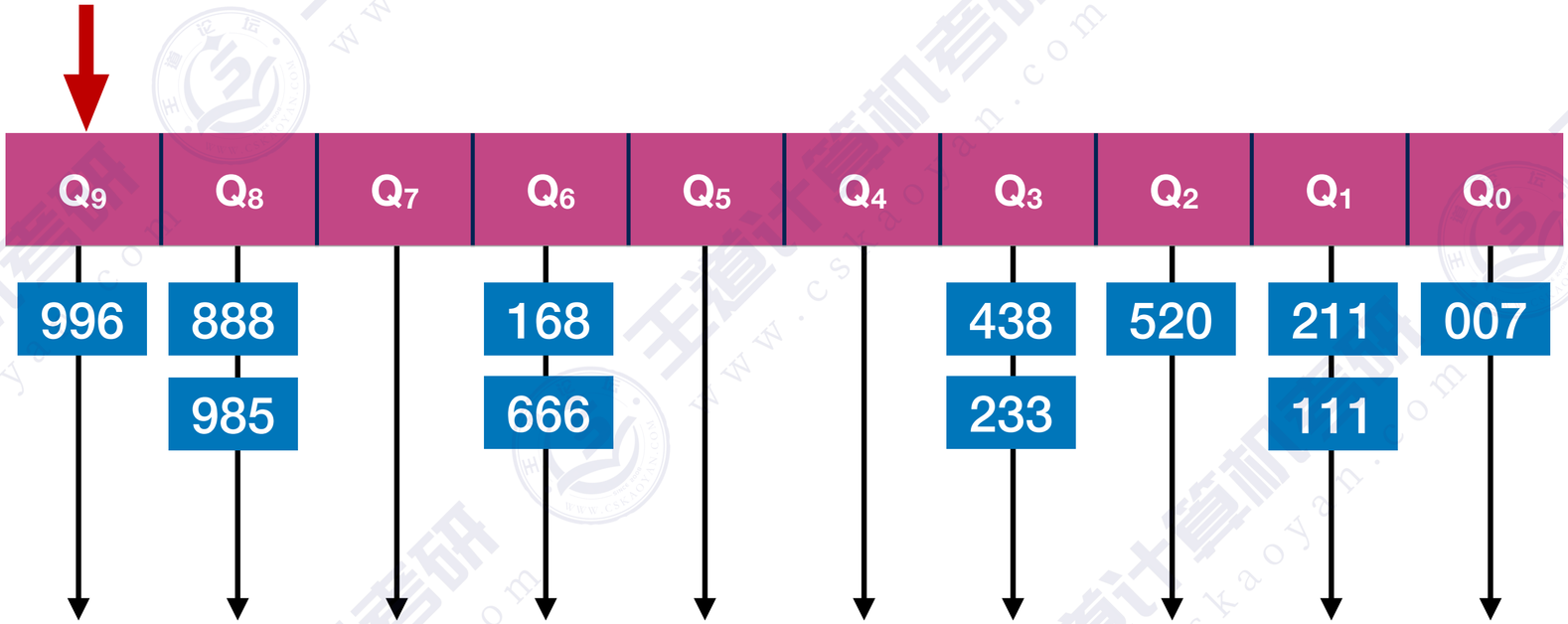
基数排序

第二趟“分配”结束



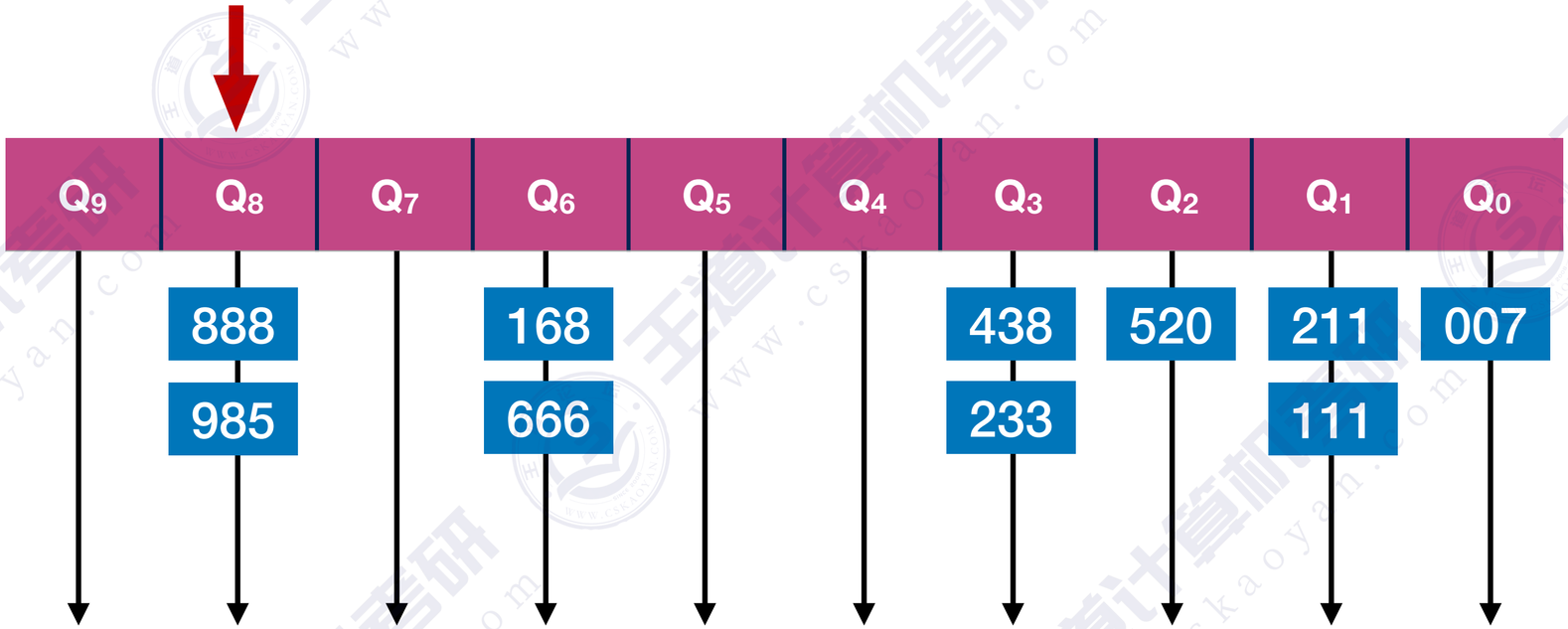
基数排序

第二趟“收集”：



基数排序

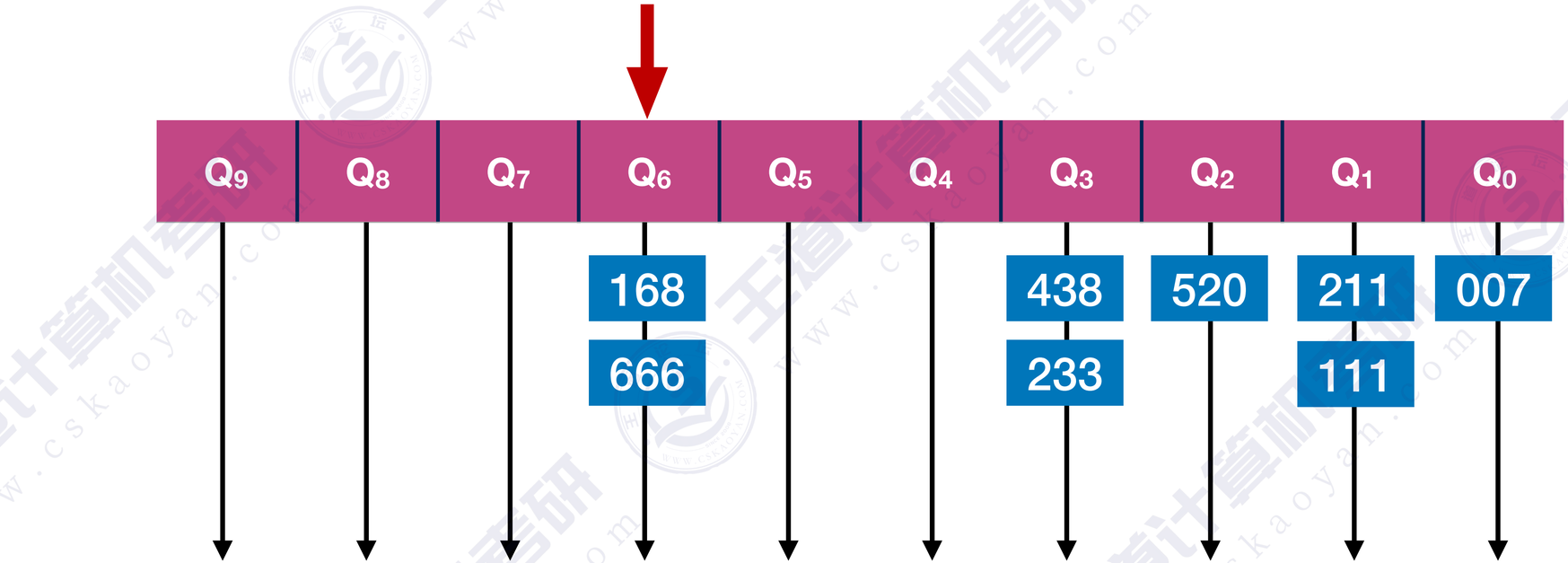
第二趟“收集”：



996

基数排序

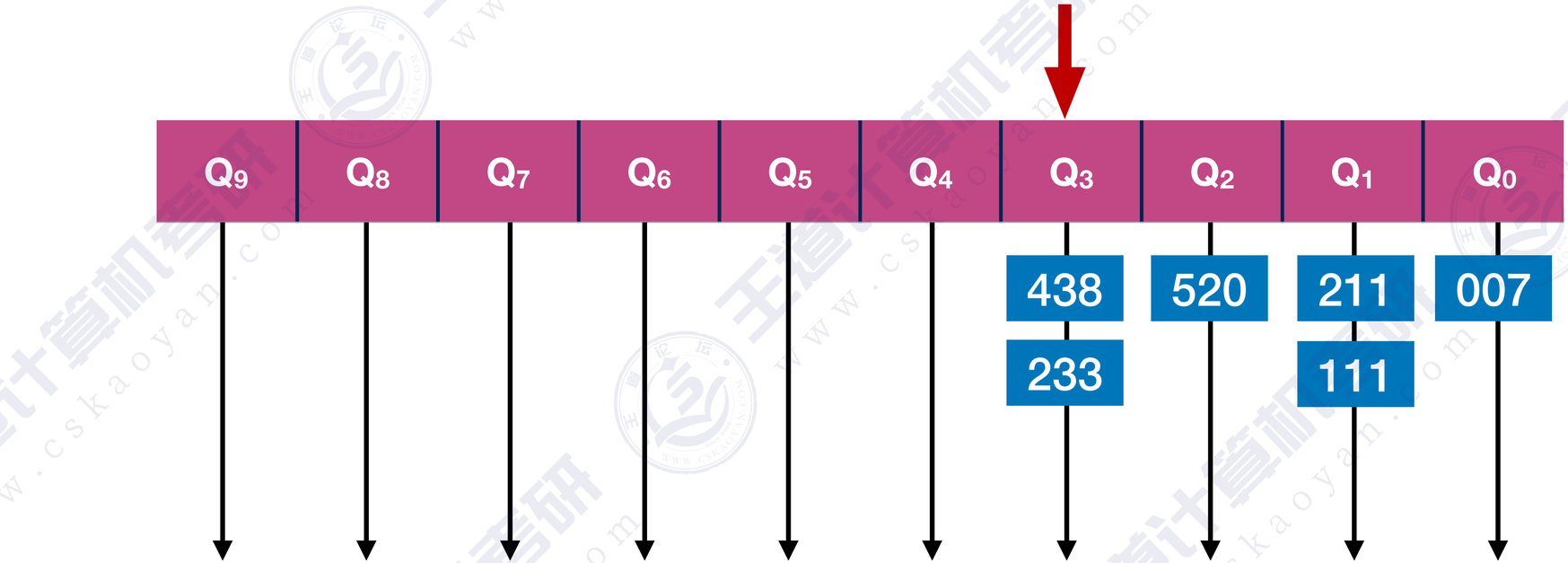
第二趟“收集”：



996 888 985

基数排序

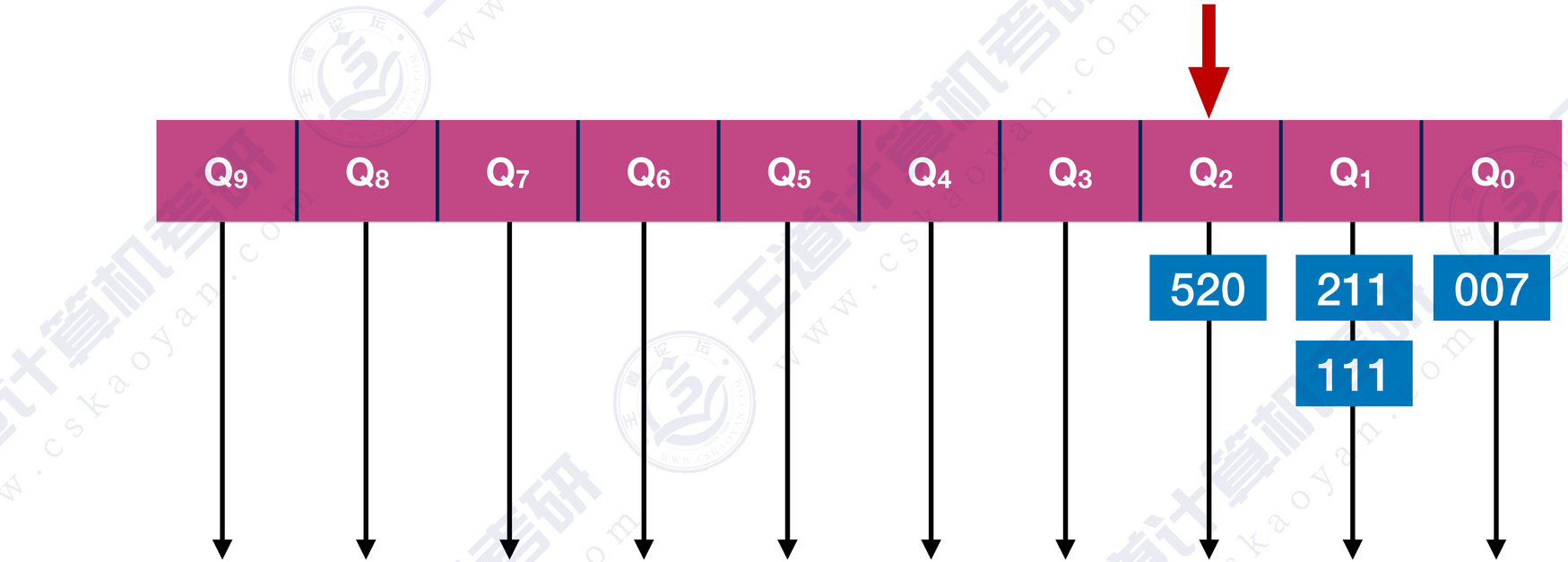
第二趟“收集”：



996 888 985 168 666

基数排序

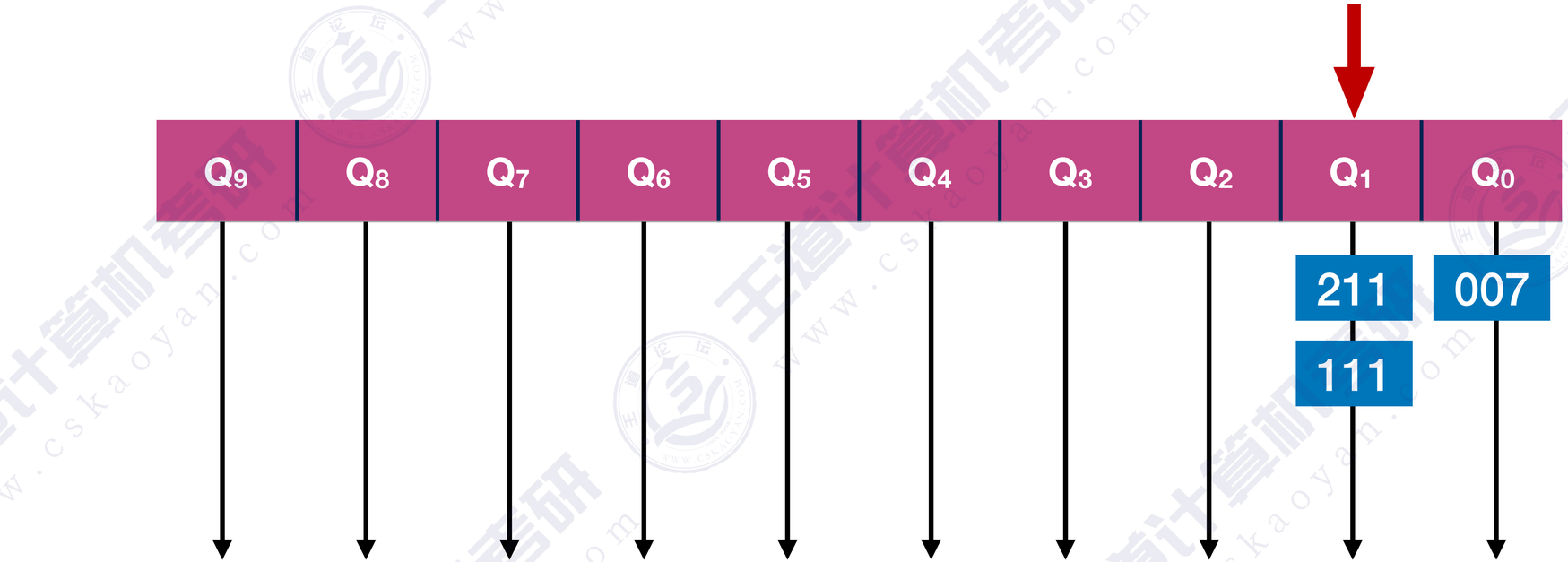
第二趟“收集”：



996 888 985 168 666 438 233

基数排序

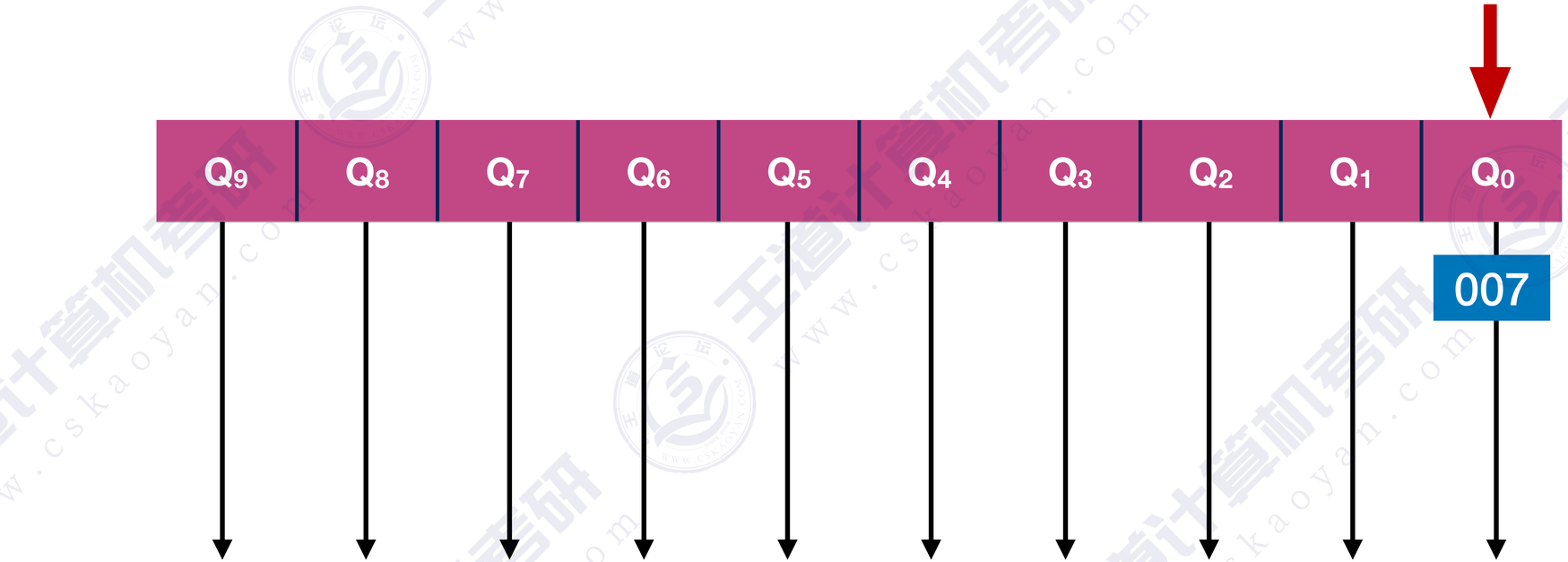
第二趟“收集”：



996 888 985 168 666 438 233 520

基数排序

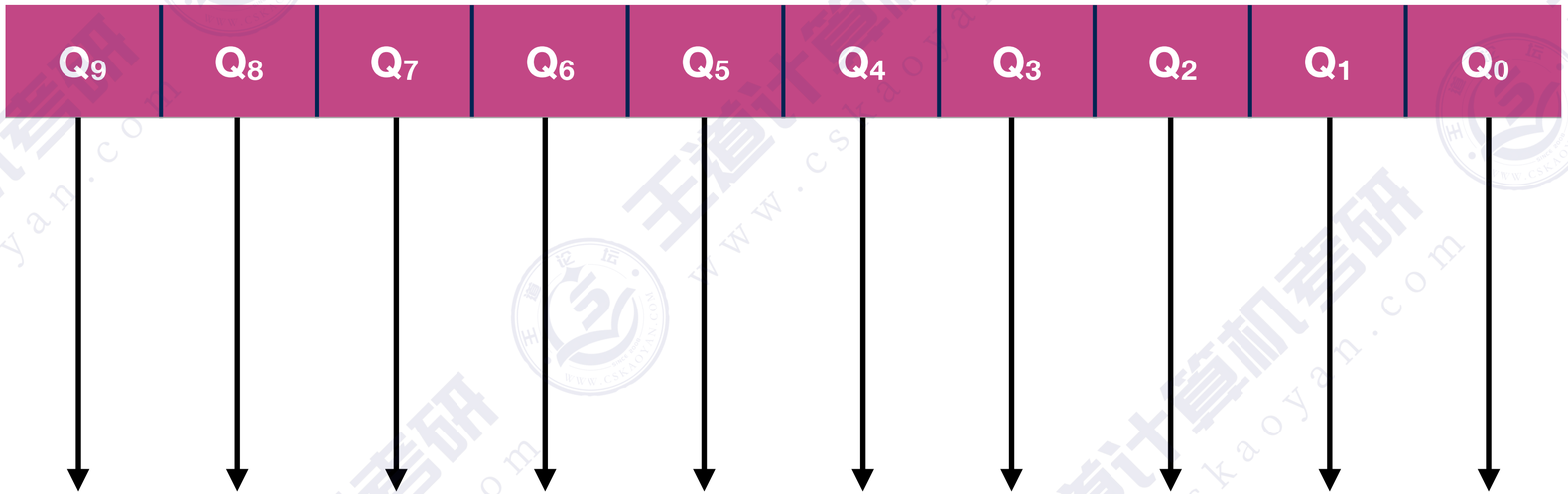
第二趟“收集”：



996 888 985 168 666 438 233 520 211 111

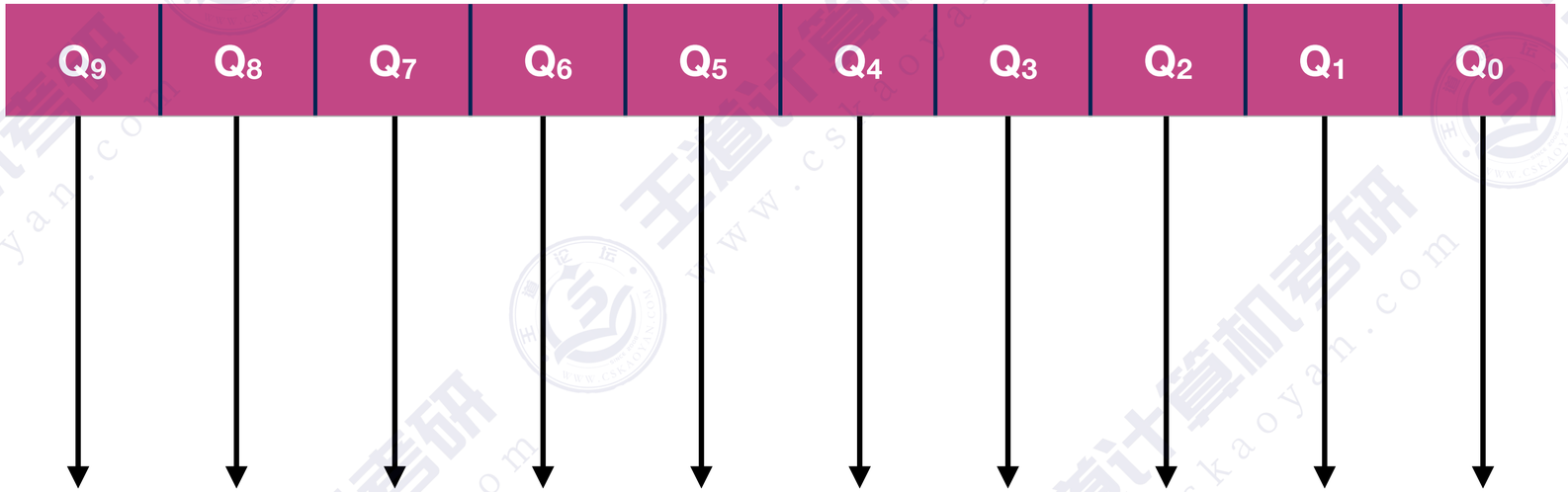
基数排序

第二趟“收集”：



996 888 985 168 666 438 233 520 211 111 007

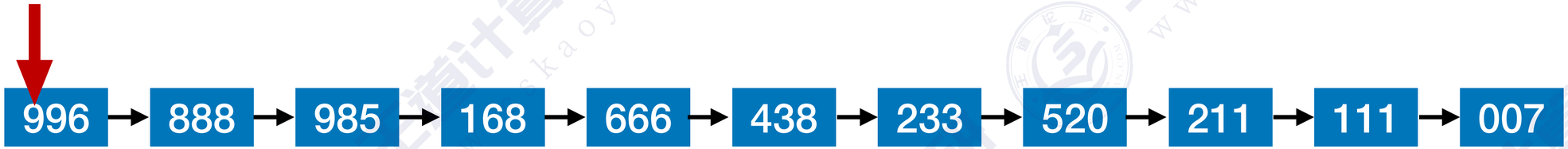
基数排序



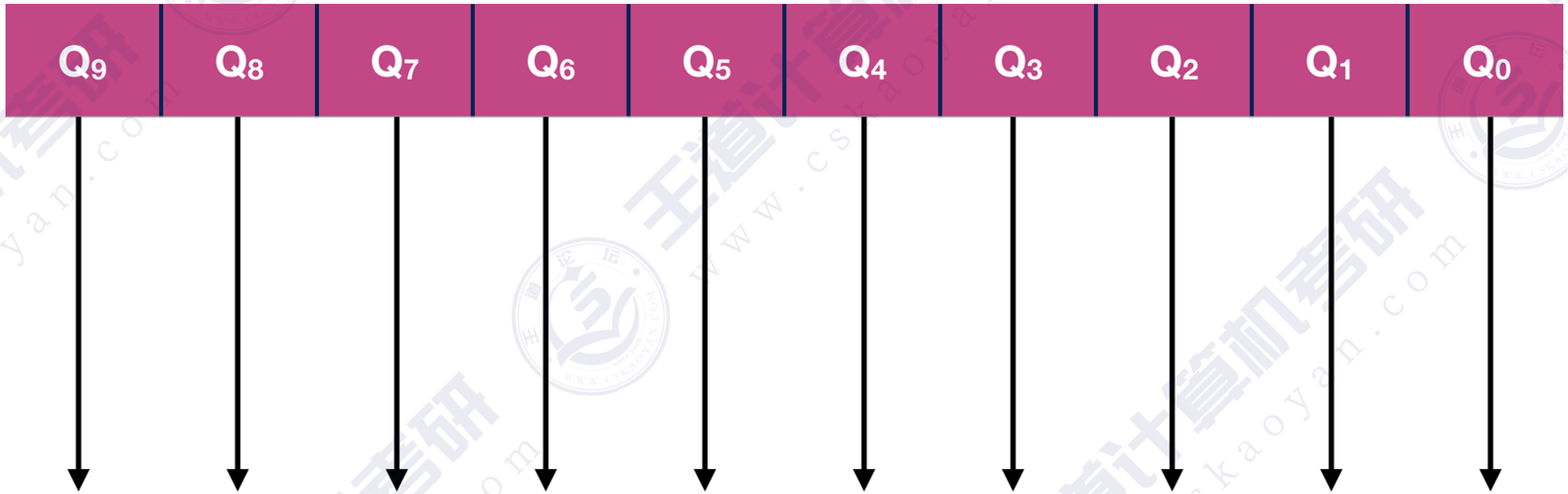
第二趟“收集”结束：得到按“十位”递减排序的序列，“十位”相同的按“个位”递减排序

996 → 888 → 985 → 168 → 666 → 438 → 233 → 520 → 211 → 111 → 007

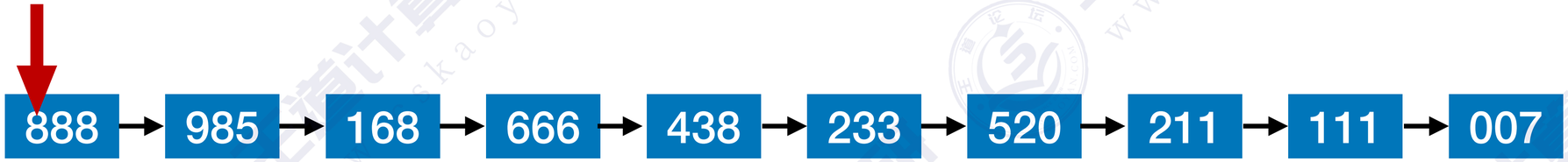
基数排序



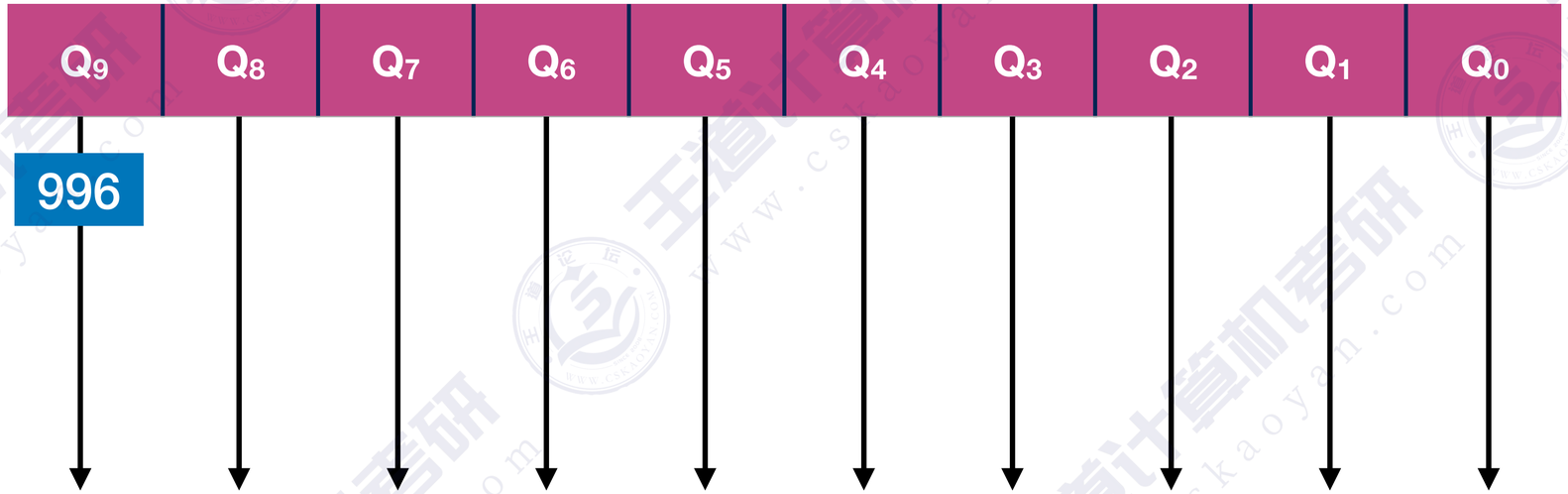
第三趟：以“百位”进行“分配”



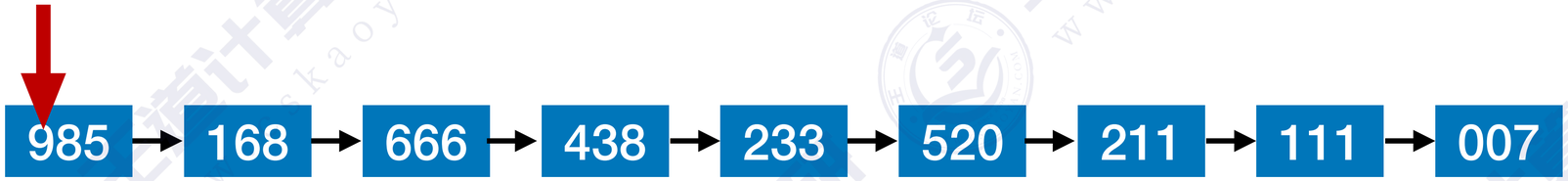
基数排序



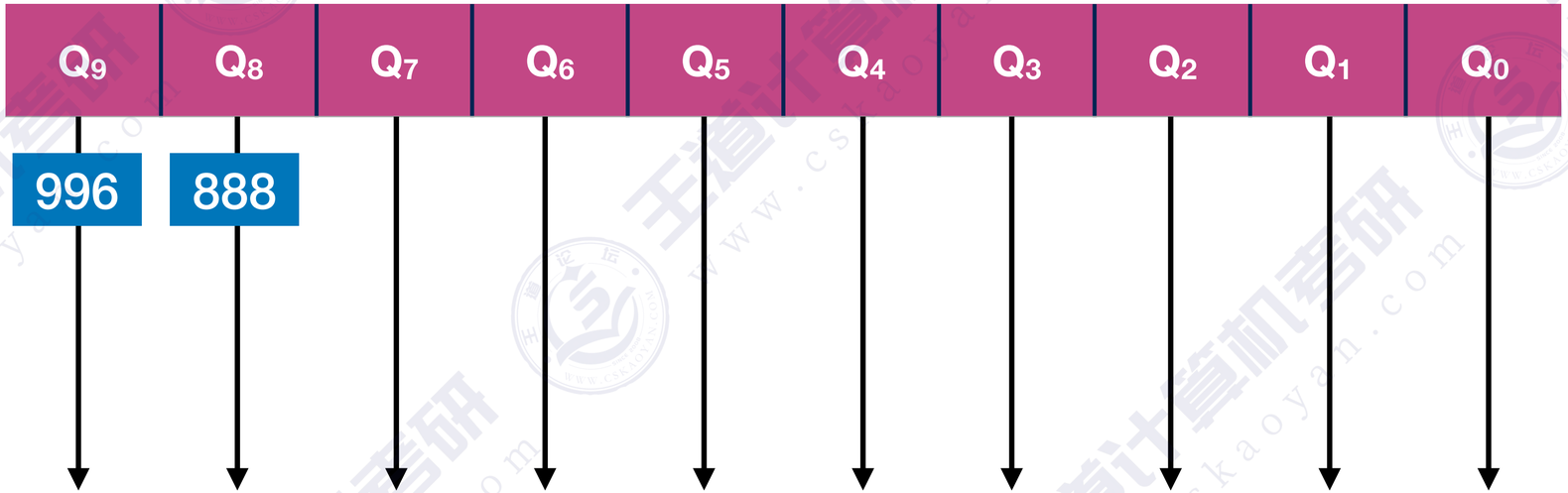
第三趟：以“百位”进行“分配”



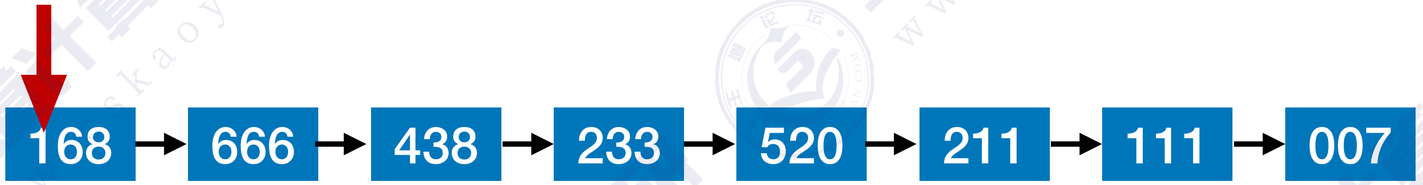
基数排序



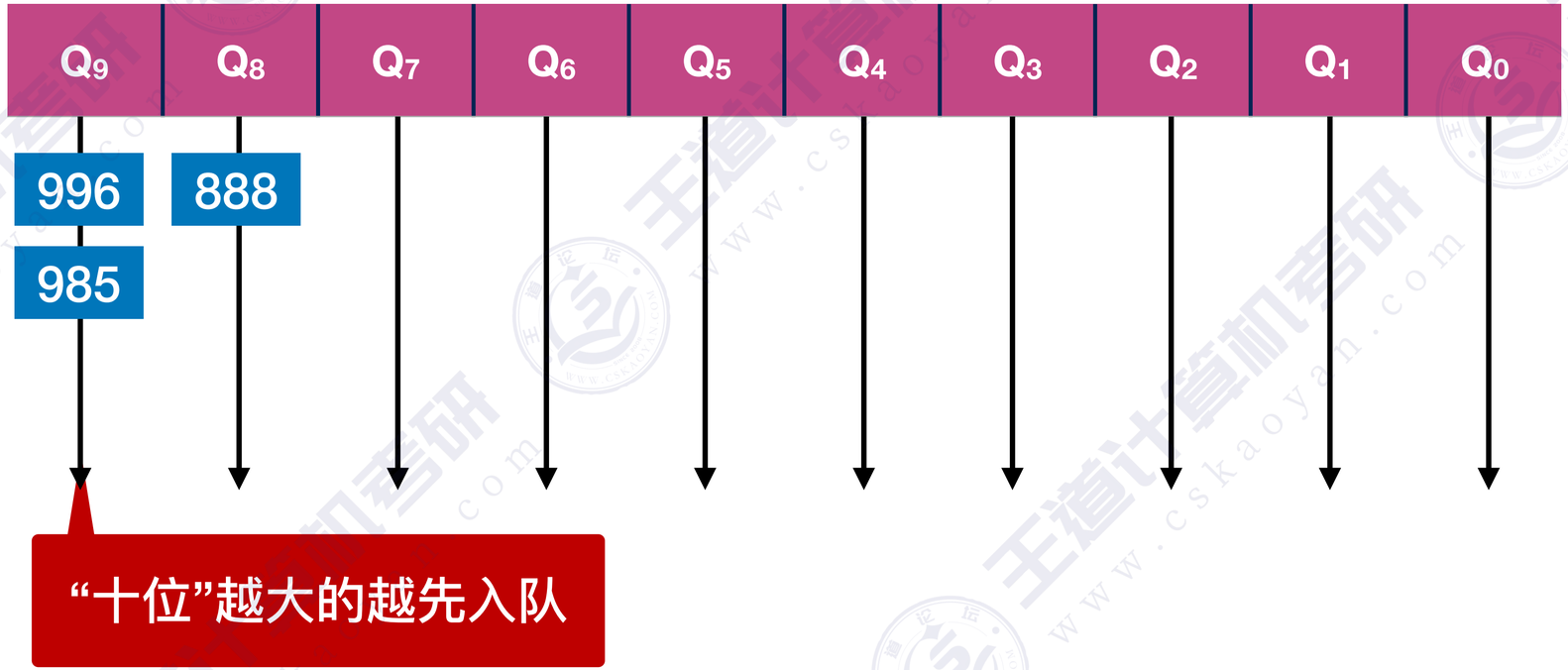
第三趟：以“百位”进行“分配”



基数排序

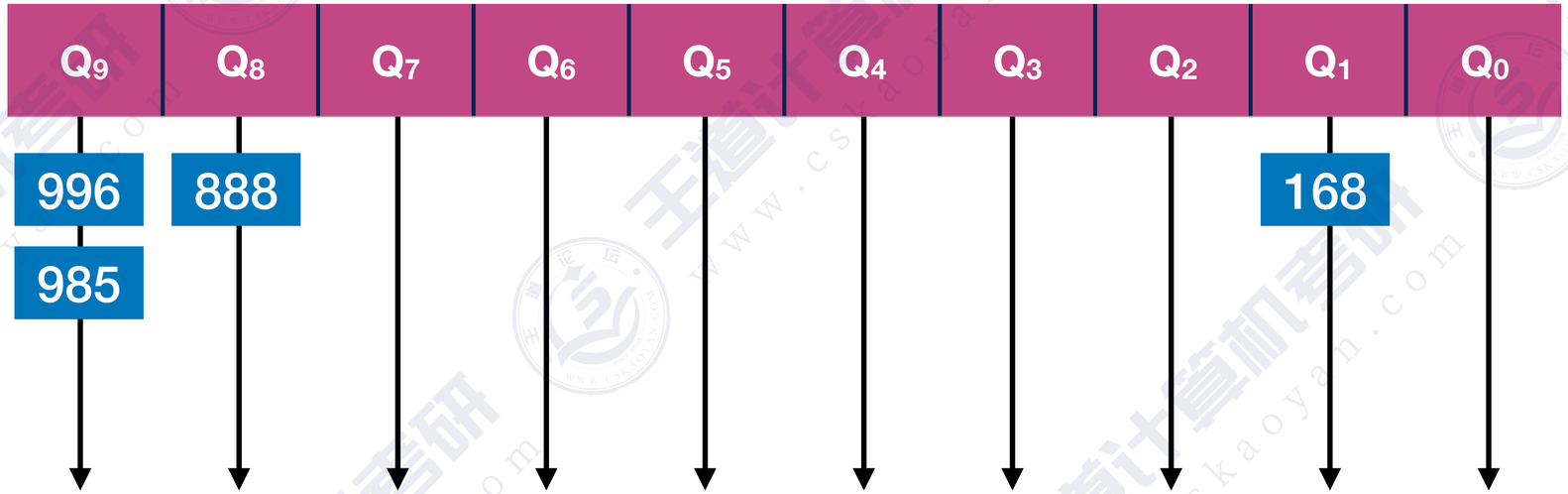


第三趟：以“百位”进行“分配”

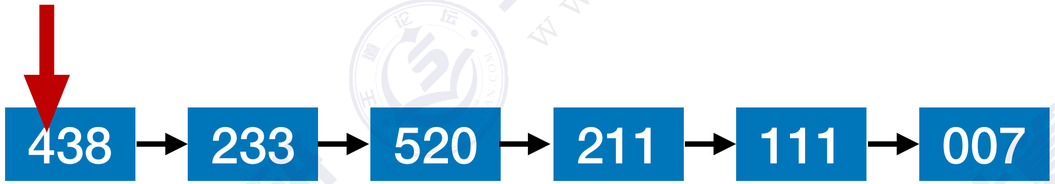


基数排序

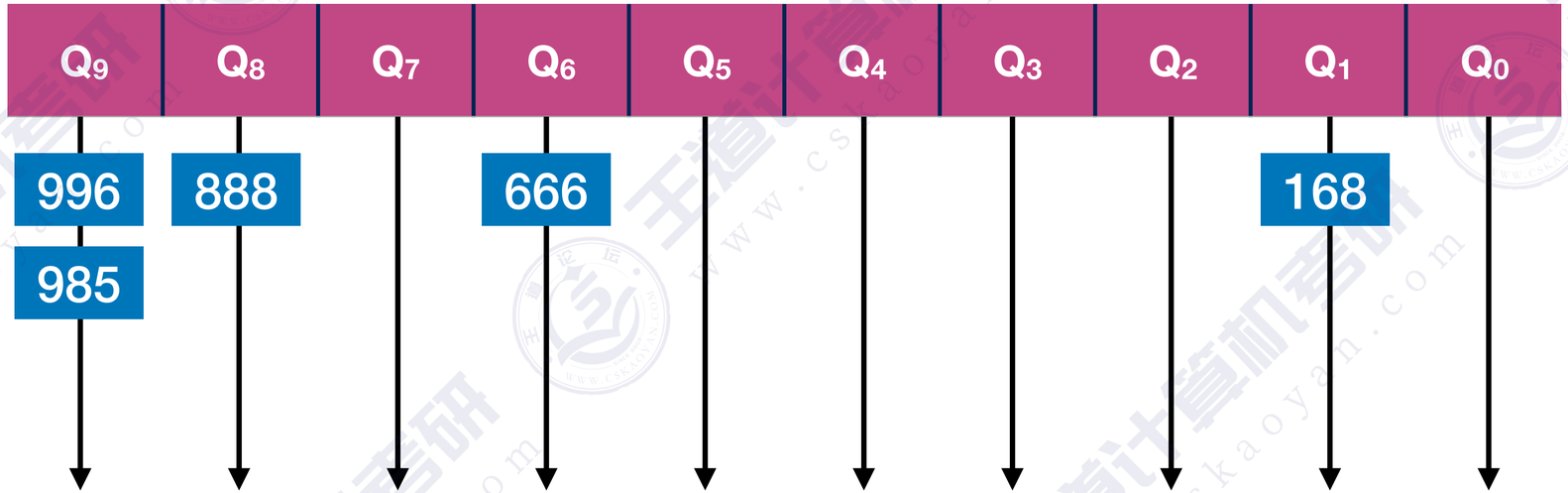
第三趟：以“百位”进行“分配”



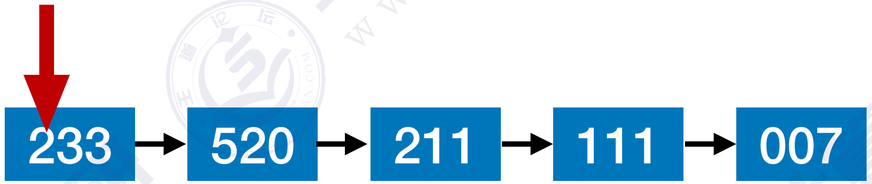
基数排序



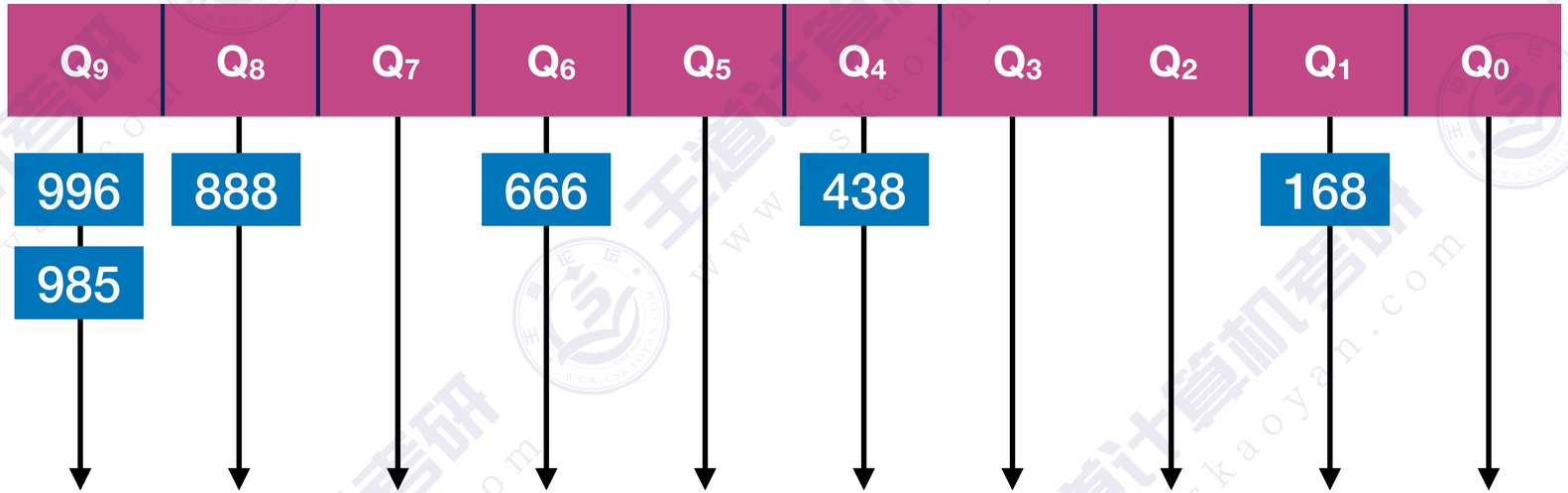
第三趟：以“百位”进行“分配”



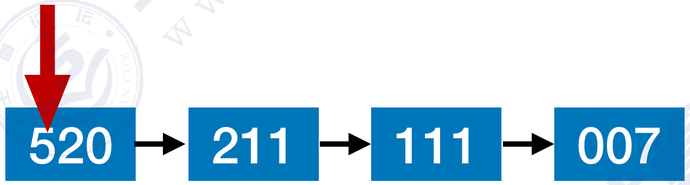
基数排序



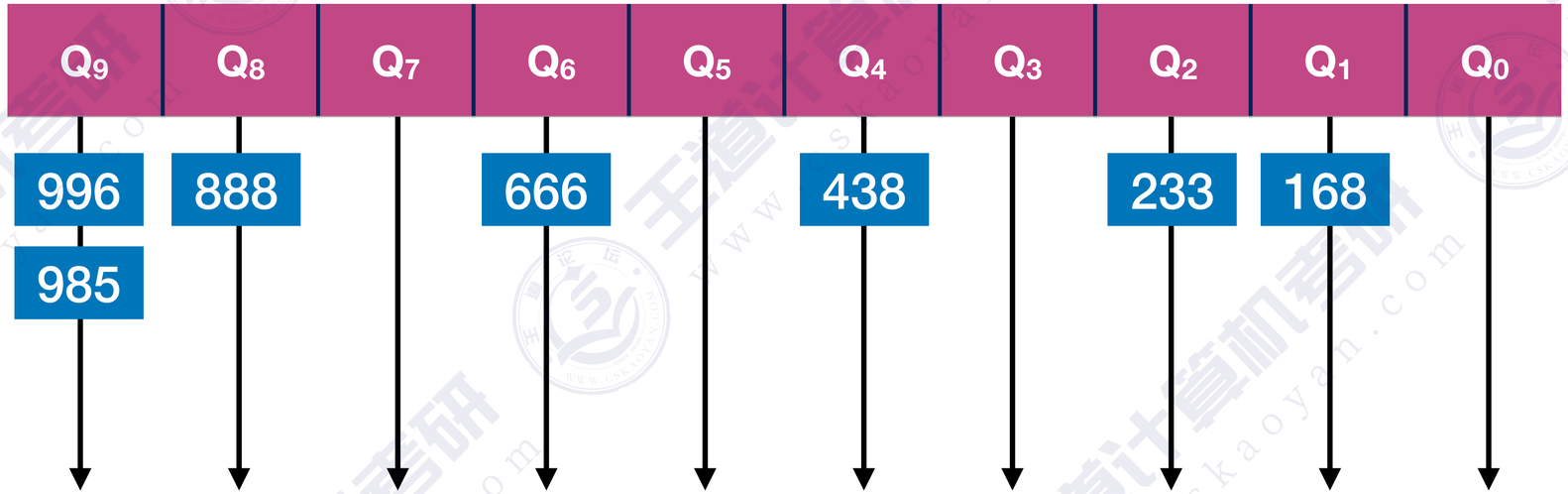
第三趟：以“百位”进行“分配”



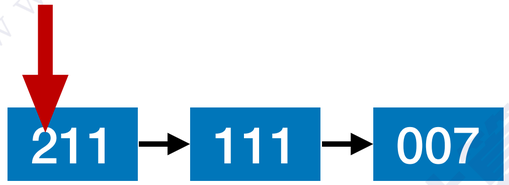
基数排序



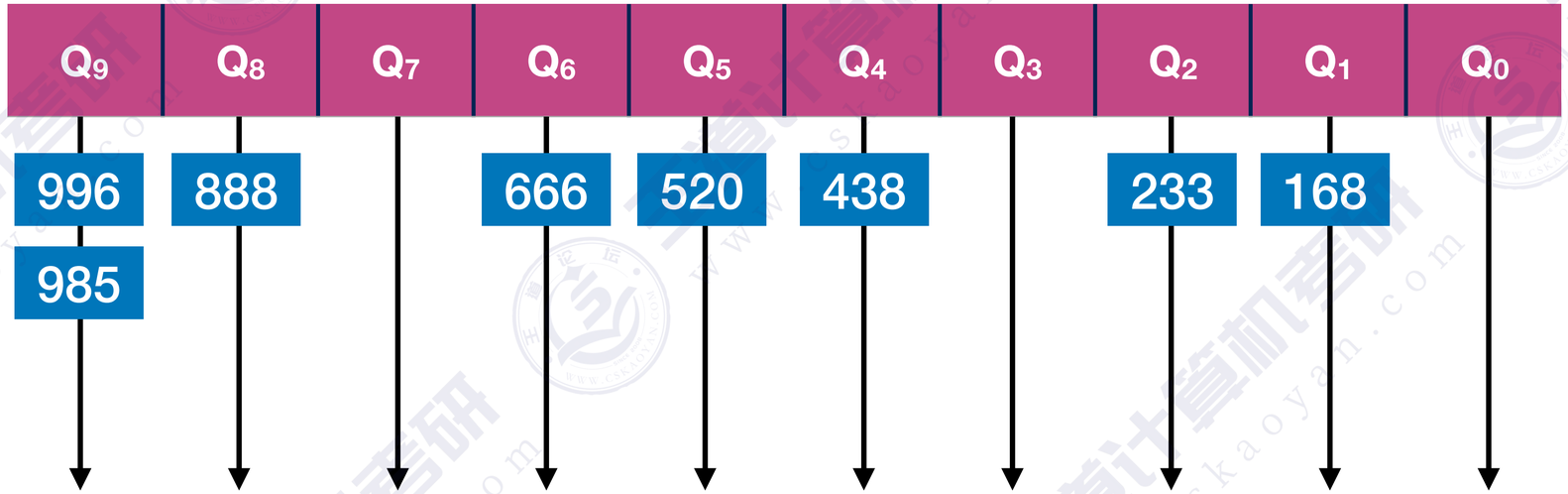
第三趟：以“百位”进行“分配”



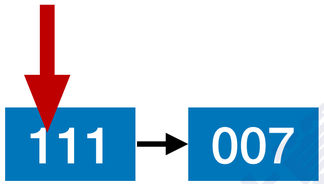
基数排序



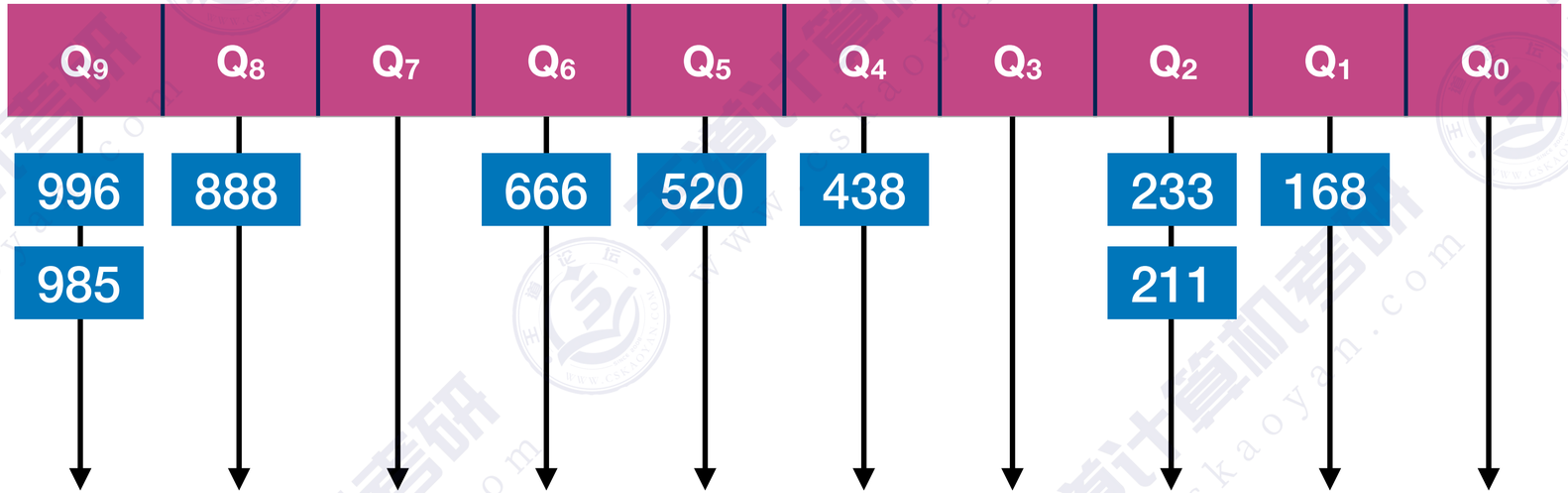
第三趟：以“百位”进行“分配”



基数排序



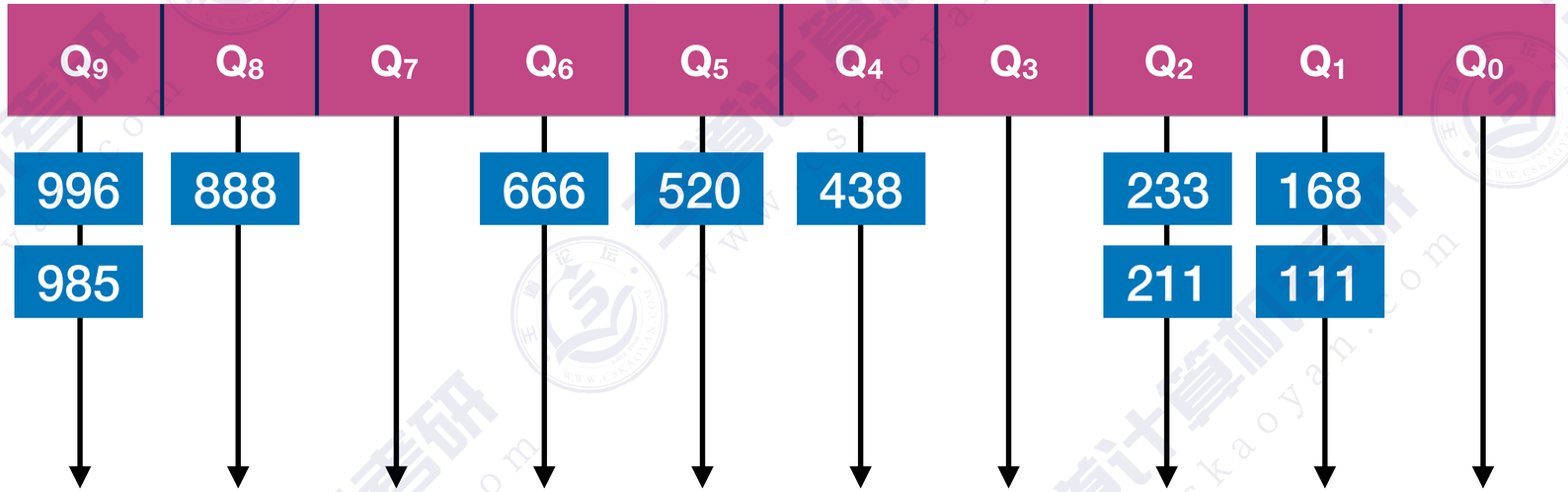
第三趟：以“百位”进行“分配”



基数排序

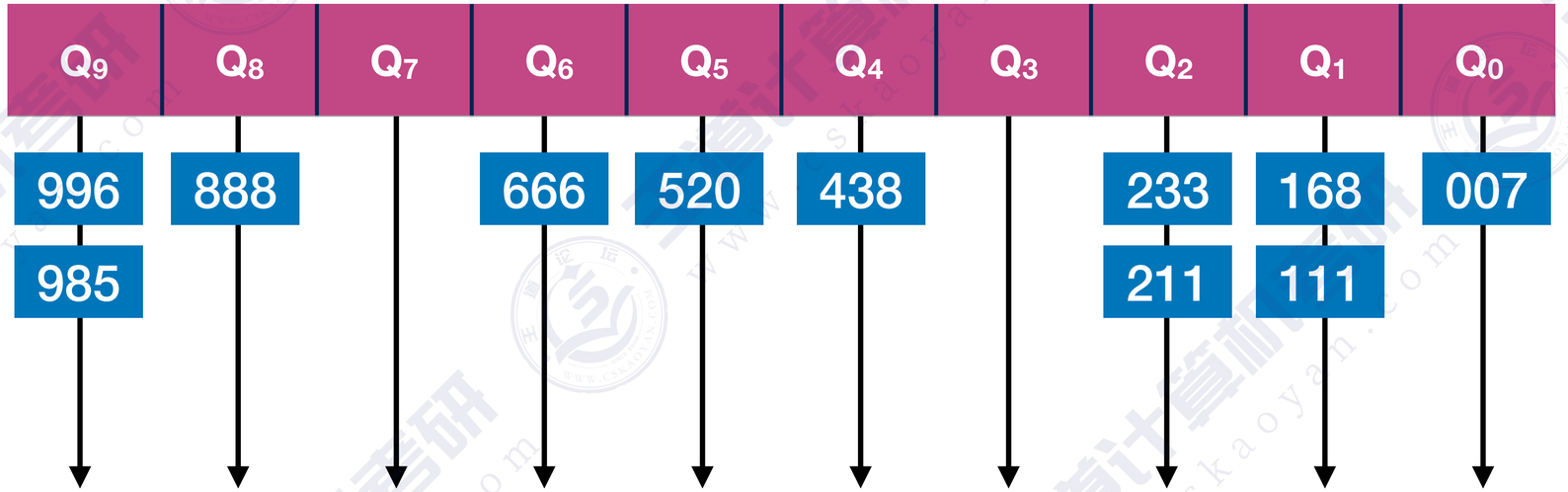
007

第三趟：以“百位”进行“分配”

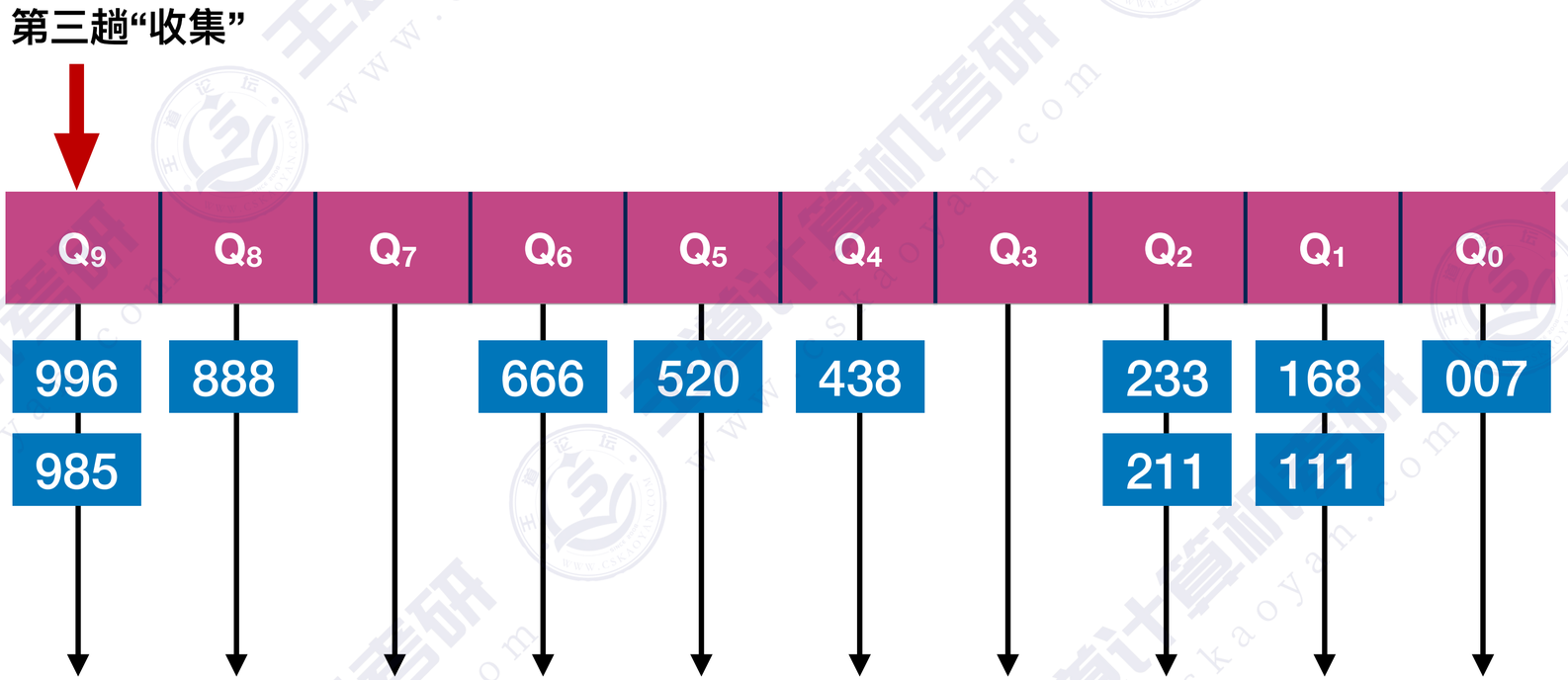


基数排序

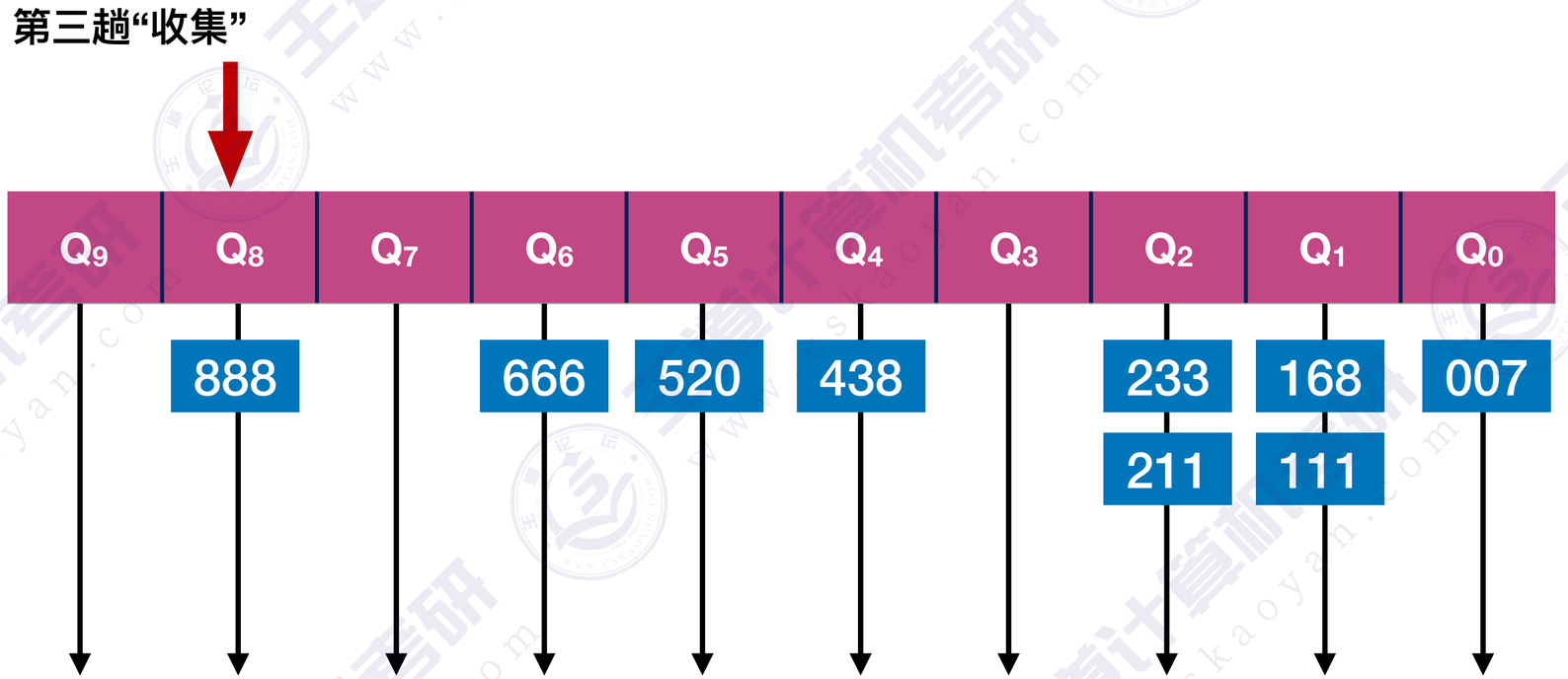
第三趟：以“百位”进行“分配”



基数排序



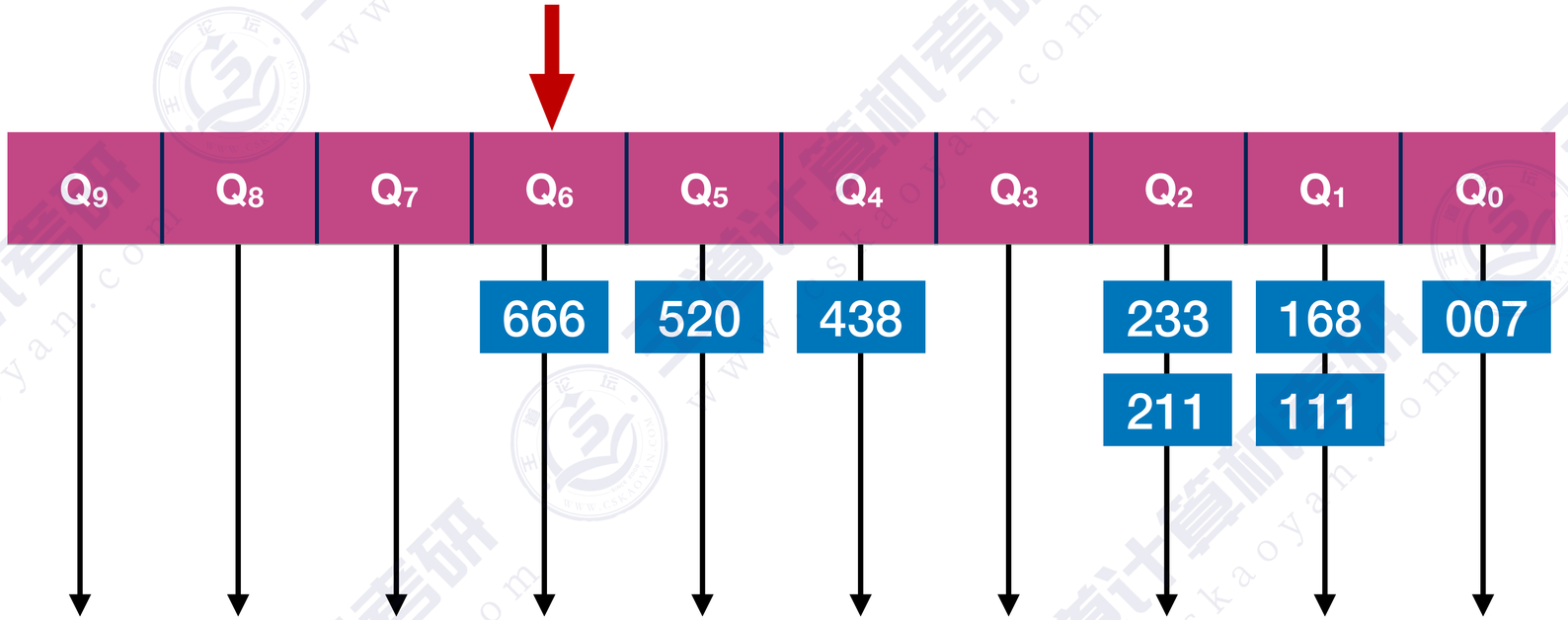
基数排序



996 985

基数排序

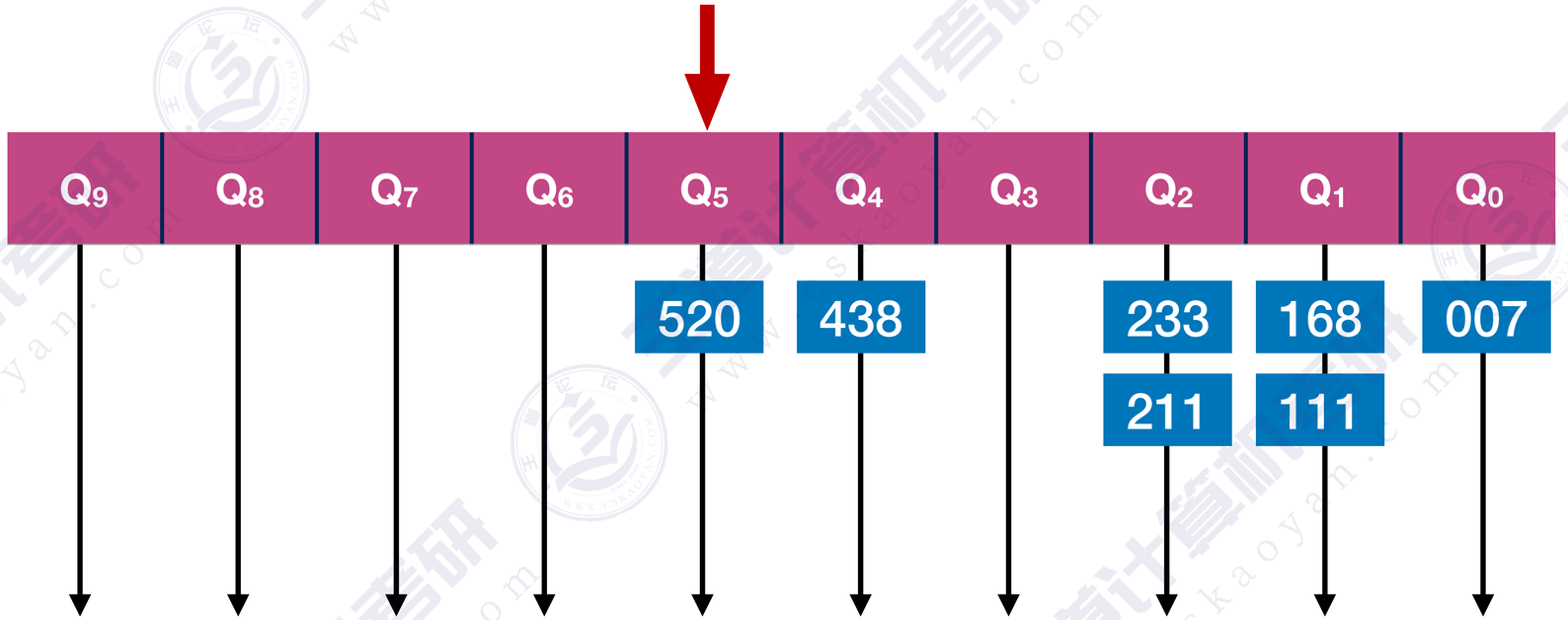
第三趟“收集”



996 985 888

基数排序

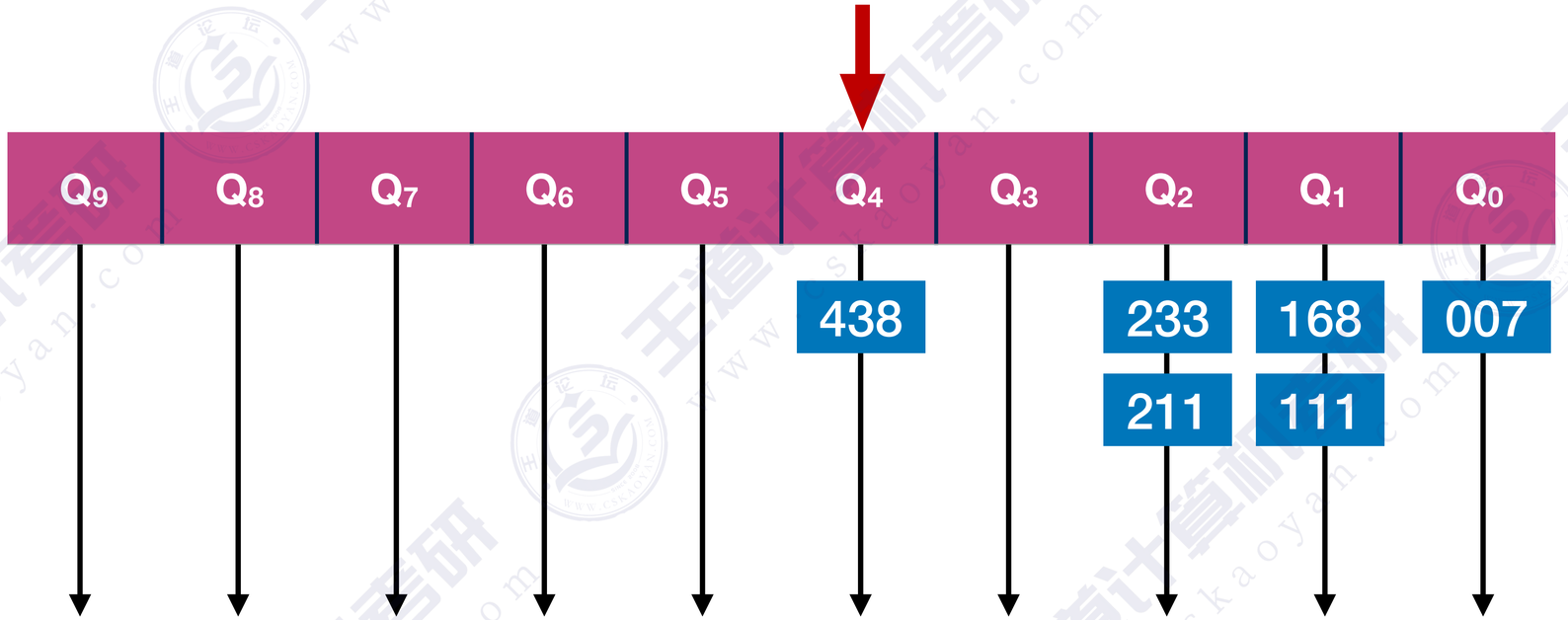
第三趟“收集”



996 985 888 666

基数排序

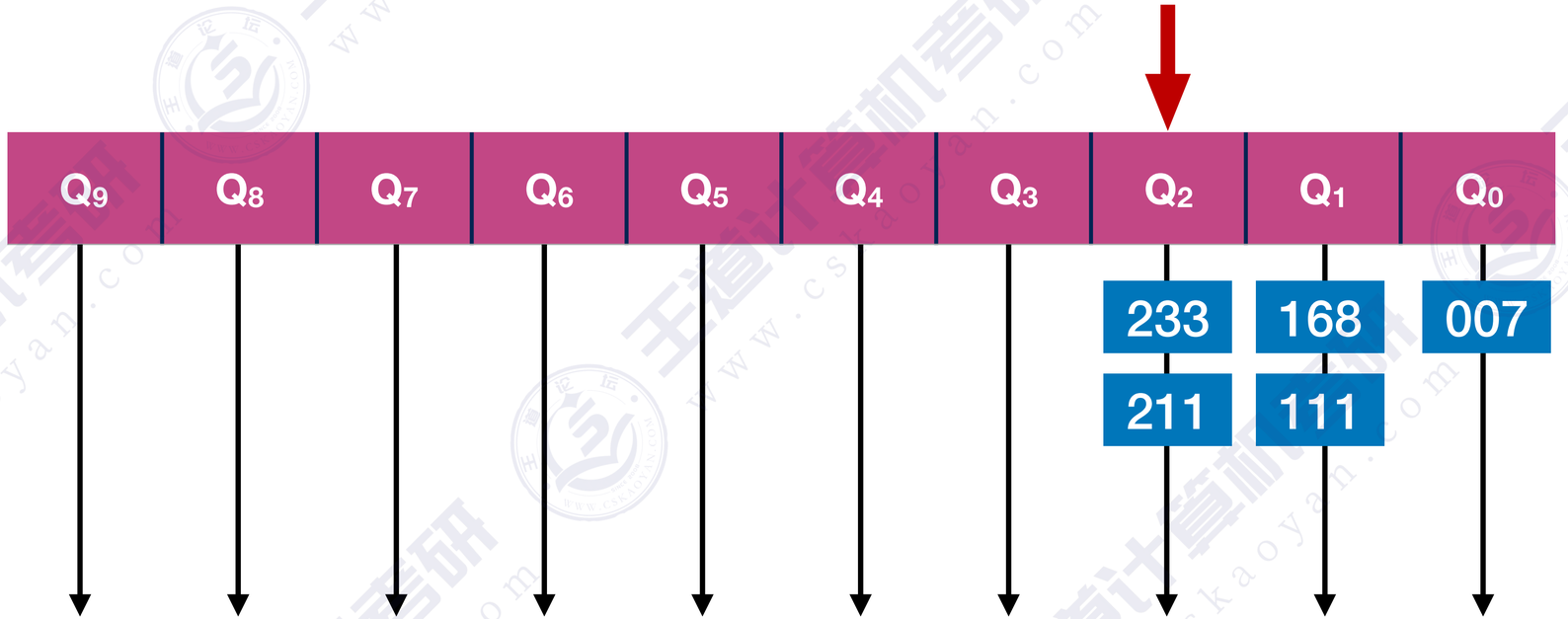
第三趟“收集”



996 985 888 666 520

基数排序

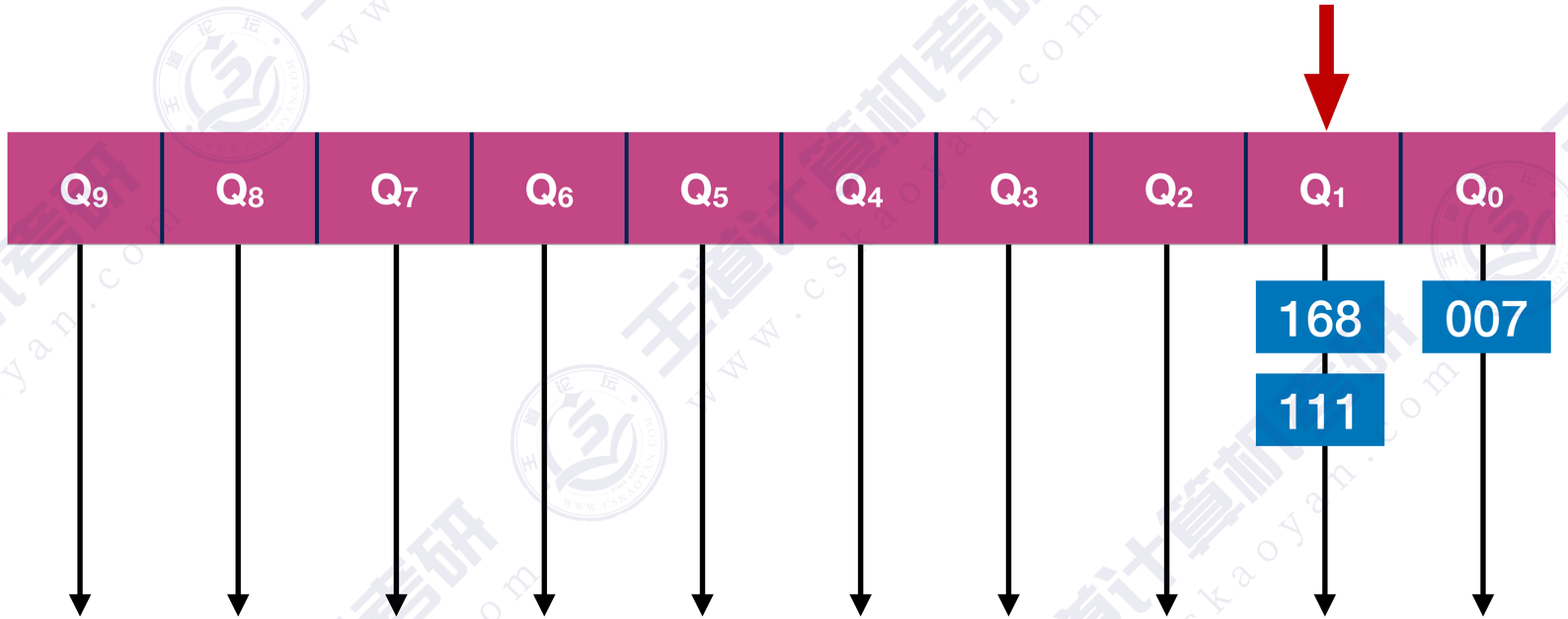
第三趟“收集”



996 985 888 666 520 438

基数排序

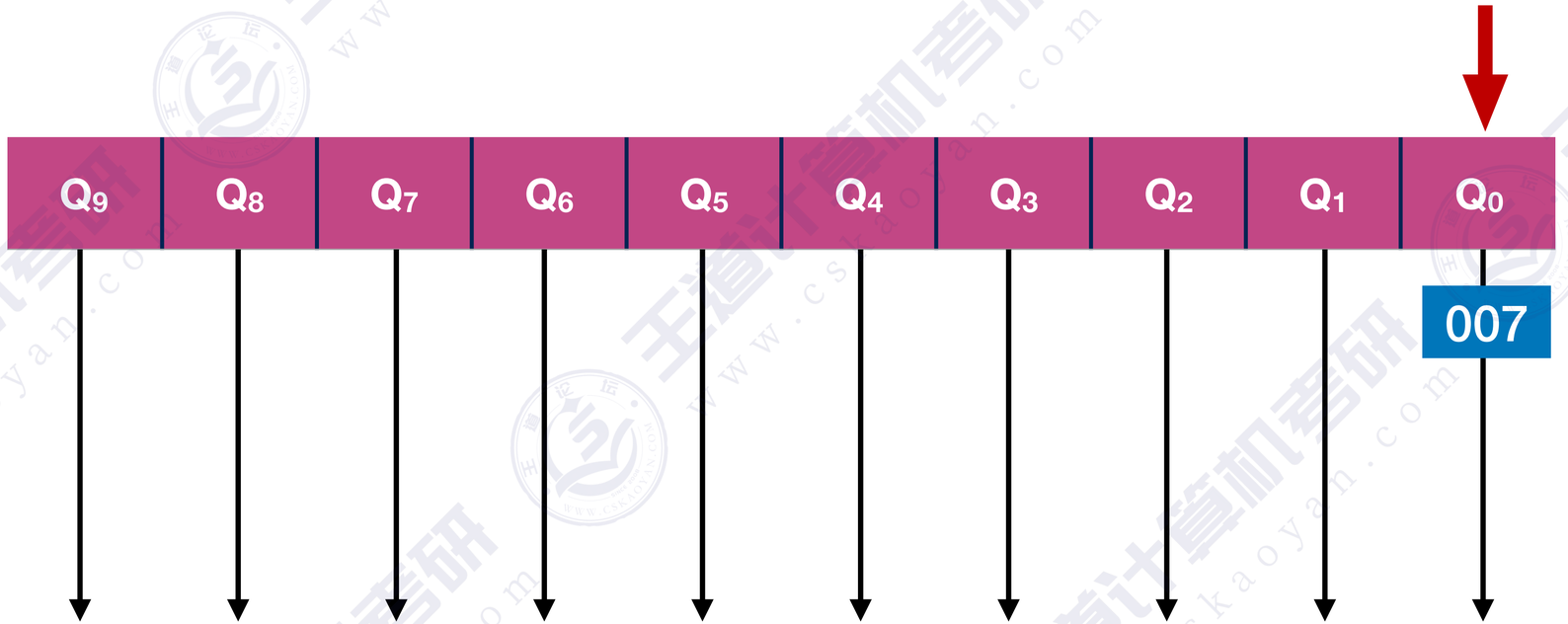
第三趟“收集”



996 985 888 666 520 438 233 211

基数排序

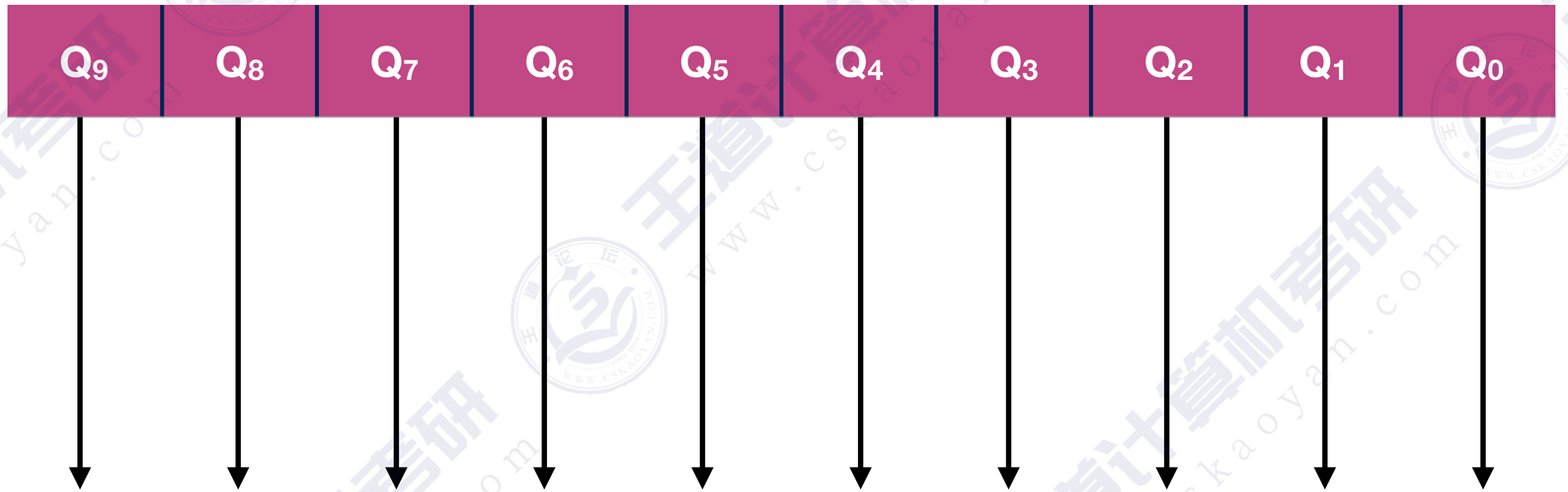
第三趟“收集”



996 985 888 666 520 438 233 211 168 111

基数排序

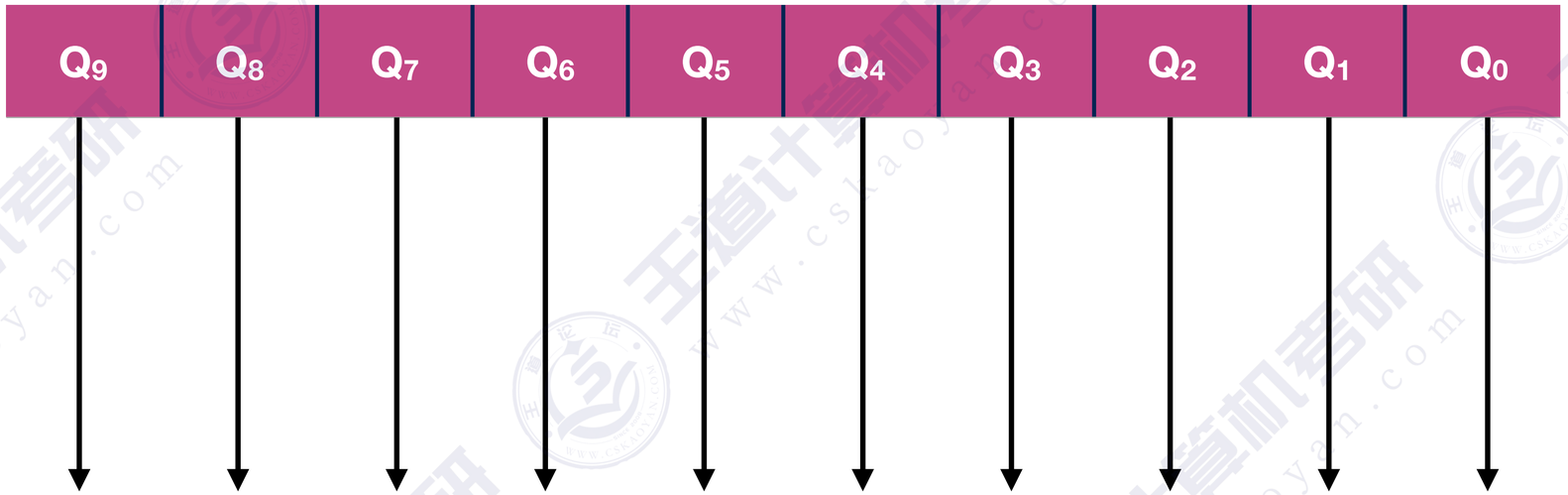
第三趟“收集”



996 985 888 666 520 438 233 211 168 111 007

基数排序

第三趟“收集”



第三趟按“百位”分配、收集：得到一个按“百位”递减排列的序列，若“百位”相同则按“十位”递减排列，若“十位”还相同则按“个位”递减排列

996 → 985 → 888 → 666 → 520 → 438 → 233 → 211 → 168 → 111 → 007

基数排序

初始序列：

520 → 211 → 438 → 888 → 007 → 111 → 985 → 666 → 996 → 233 → 168

第一趟按“个位”分配、收集：得到按“个位”递减排序的序列

438 → 888 → 168 → 007 → 666 → 996 → 985 → 233 → 211 → 111 → 520

第二趟按“十位”分配、收集：得到按“十位”递减排序的序列，“十位”相同的按“个位”递减排序

996 → 888 → 985 → 168 → 666 → 438 → 233 → 520 → 211 → 111 → 007

第三趟按“百位”分配、收集：得到一个按“百位”递减排列的序列，若“百位”相同则按“十位”递减排列，若“十位”还相同则按“个位”递减排列

996 → 985 → 888 → 666 → 520 → 438 → 233 → 211 → 168 → 111 → 007

基数排序

初始序列：

520 → 211 → 438 → 888 → 007 → 111 → 985 → 666 → 996 → 233 → 168

最高位关键字（最主位关键字）

最低位关键字（最次位关键字）

假设长度为n的线性表中每个结点a_j的关键字由d元组 $(k_j^{d-1}, k_j^{d-2}, k_j^{d-3}, \ldots, k_j^1, k_j^0)$ 组成

其中，$0 \le k_j^i \le r-1$ $(0 \le j < n,\ 0 \le i \le d-1)$，r 称为“基数”

基数排序不是基于“比较”的排序算法

基数排序得到递减序列的过程如下，

初始化： 设置 r 个空队列，$Q_{r-1}, Q_{r-2}, \ldots, Q_0$

按照各个 关键字位 权重递增的次序（个、十、百），对 d 个关键字位分别做“分配”和“收集”

分配：顺序扫描各个元素，若当前处理的关键字位=x，则将元素插入 Q_x 队尾

收集：把 $Q_{r-1}, Q_{r-2}, \ldots, Q_0$ 各个队列中的结点依次出队并链接

基数排序

初始序列：

520 → 211 → 438 → 888 → 007 → 111 → 985 → 666 → 996 → 233 → 168

最高位关键字（最主位关键字）

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基数排序不是基于“比较”的排序算法

基数排序得到递增序列的过程如下，

初始化： 设置 r 个空队列，$Q_0, Q_1, \ldots, Q_{r-1}$

按照各个 关键字位 权重递增的次序（个、十、百），对 d 个关键字位分别做“分配”和“收集”

分配：顺序扫描各个元素，若当前处理的关键字位=x，则将元素插入 Q_x 队尾

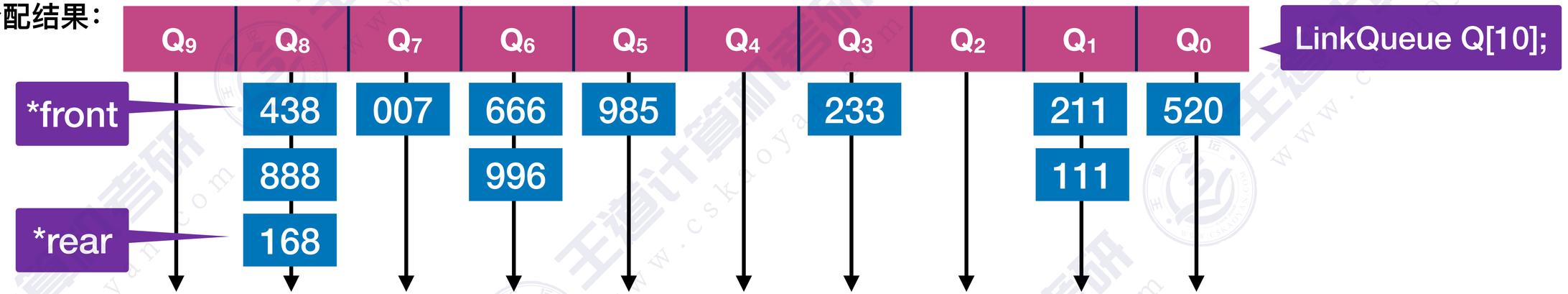
收集：把 $Q_0, Q_1, \ldots, Q_{r-1}$ 各个队列中的结点依次出队并链接

算法效率分析

初始序列：

520 → 211 → 438 → 888 → 007 → 111 → 985 → 666 → 996 → 233 → 168

第一趟分配结果：



基数排序通常基于链式存储实现

```
typedef struct LinkNode{
    ElemType data;
    struct LinkNode *next;
}LinkNode, *LinkList;
```

```
typedef struct{                    //链式队列
    LinkNode *front,*rear;   //队列的队头和队尾指针
}LinkQueue;
```

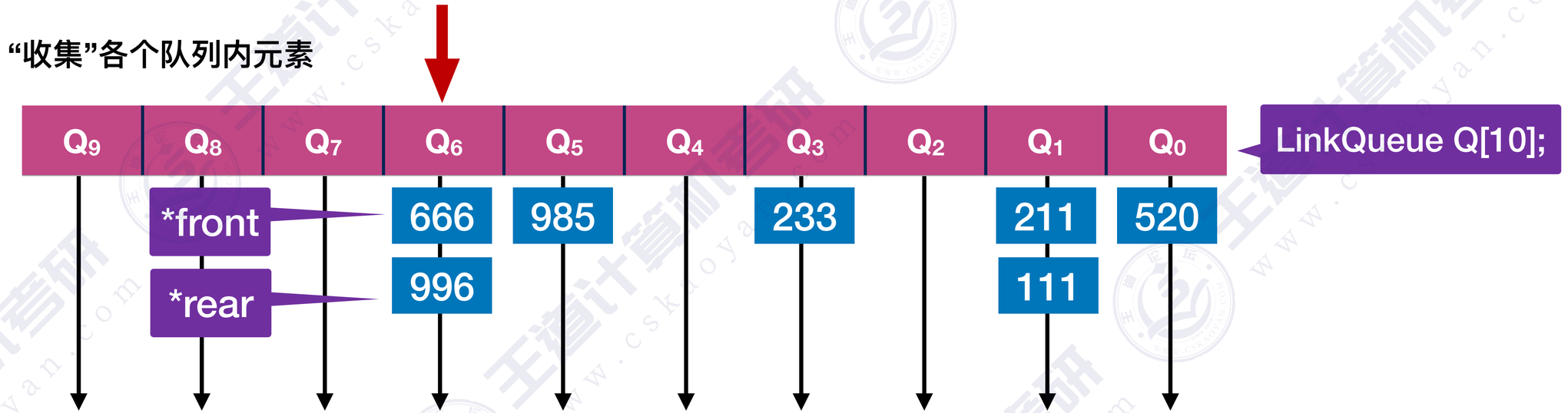
需要 r 个辅助队列，空间复杂度 = O(r)

把关键字拆为d个部分

每个部分可能取得 r 个值

一趟分配O(n)，一趟收集O(r)，总共 d 趟分配、收集，总的时间复杂度=O(d(n+r))

算法效率分析




```
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}LinkNode, *LinkList;
```
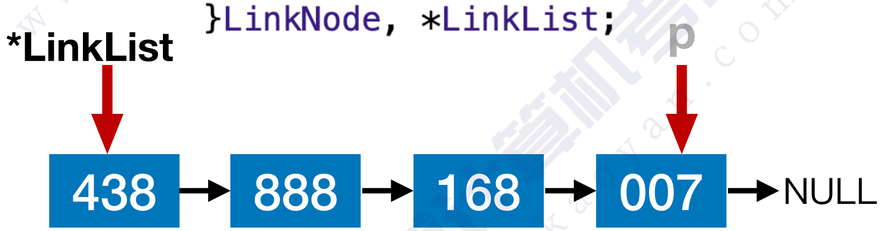
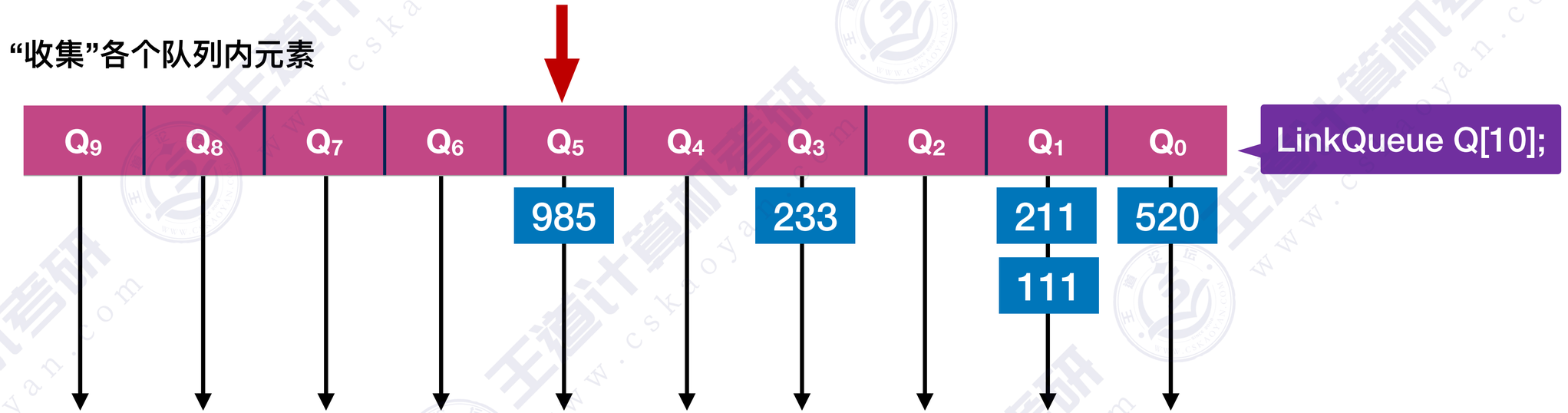

```
typedef struct{                    //链式队列
    LinkNode *front,*rear;   //队列的队头和队尾指针
}LinkQueue;
```



p->next = Q[6].front;
Q[6].front=NULL;
Q[6].rear=NULL;

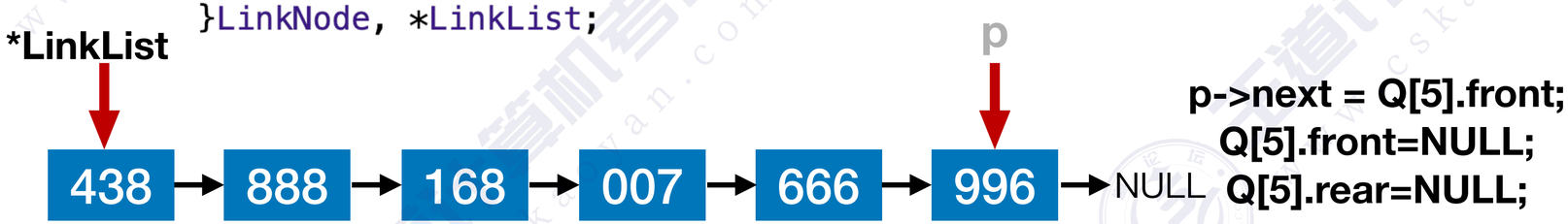
收集一个队列只需O(1)时间

算法效率分析




```
typedef struct LinkNode{
    ElemType data;
    struct LinkNode *next;
}LinkNode, *LinkList;
```

```
typedef struct{                    //链式队列
    LinkNode *front,*rear;   //队列的队头和队尾指针
}LinkQueue;
```



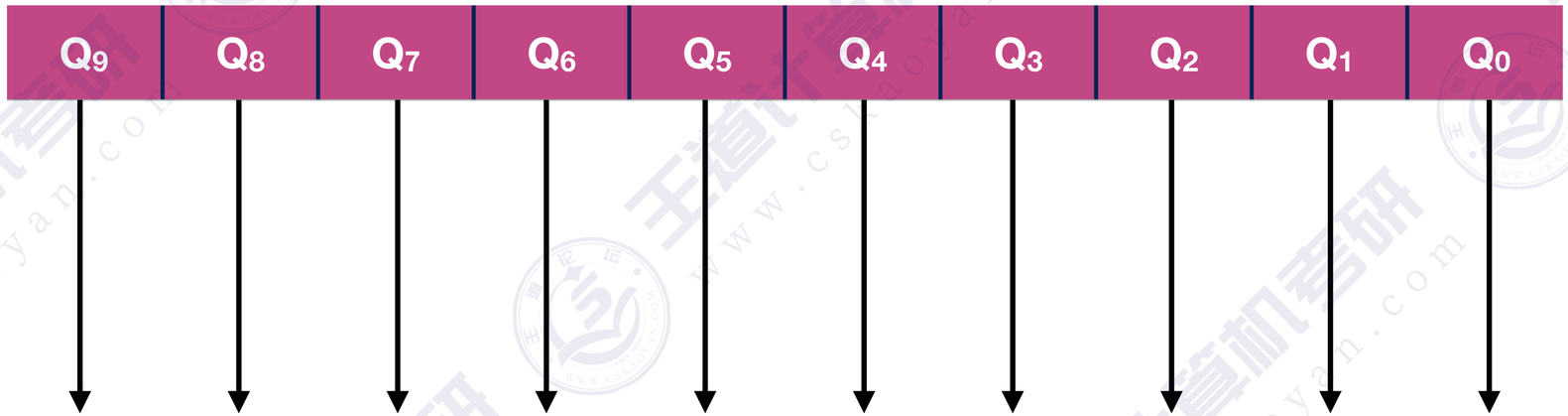
p->next = Q[5].front;
Q[5].front=NULL;
Q[5].rear=NULL;

收集一个队列只需O(1)时间

稳定性

初始序列：

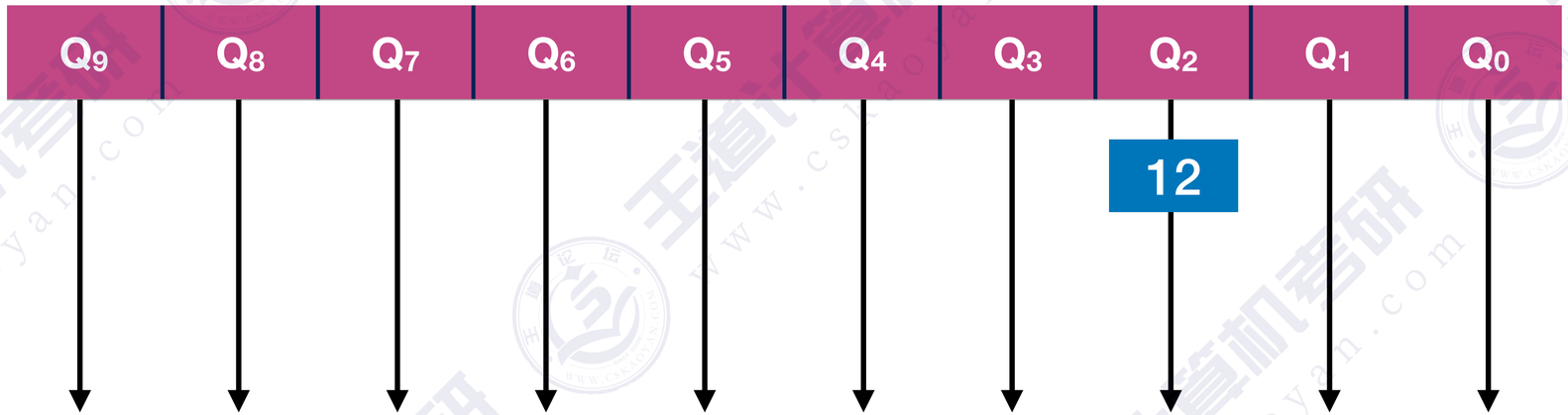
第一趟分配：



稳定性

初始序列：

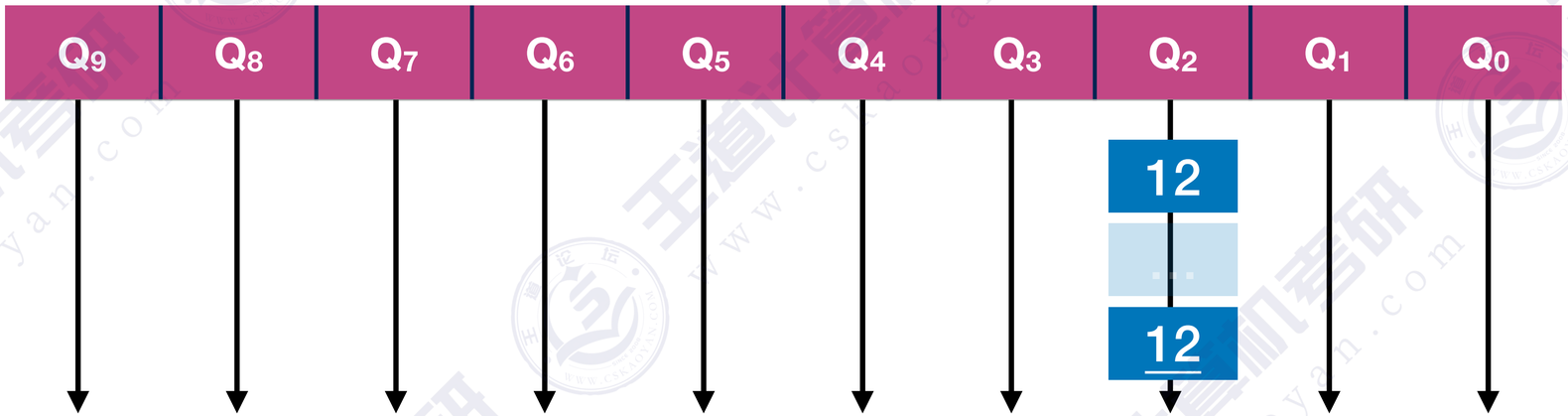
第一趟分配：



稳定性

初始序列：…… → → …… → → ……

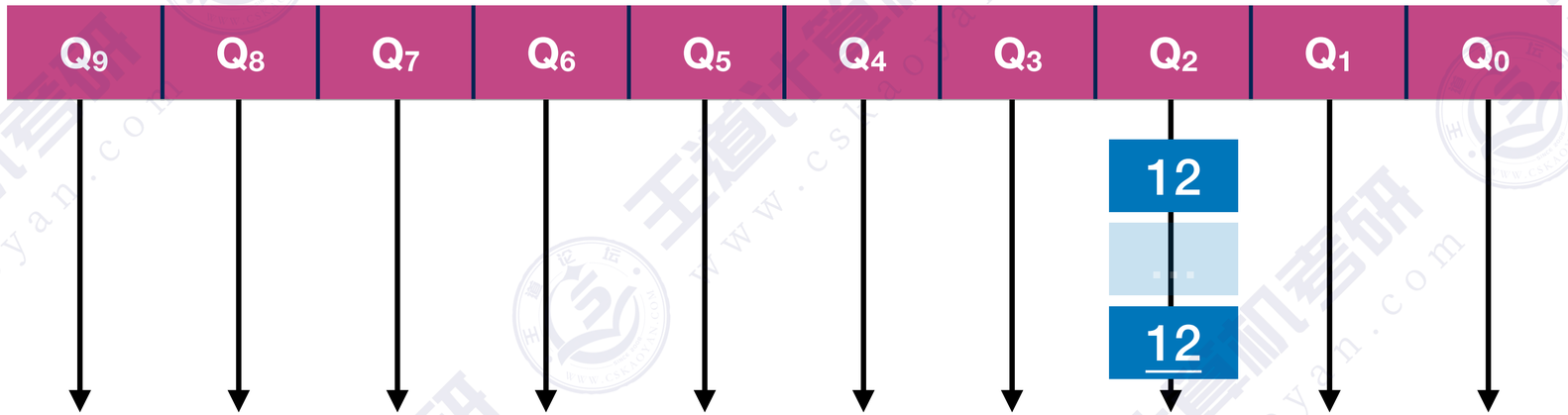
第一趟分配：



稳定性

初始序列：…… → 12 → …… → 12 → ……

第一趟分配：



第一趟收集：…… → 12 → ... → 12 → ……

基数排序是稳定的

基你太稳

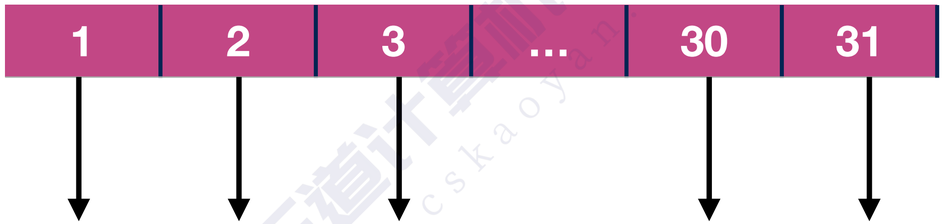
基数排序的应用

某学校有 10000 学生，将学生信息按年龄递减排序

生日可拆分为三组关键字：年(1991~2005)、月(1~12)、日(1~31)

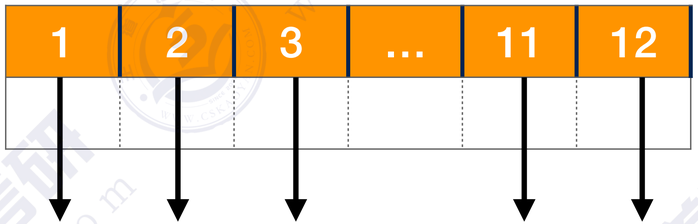
权重：年>月>日

第一趟分配、收集（按“日”递增）：



年、月、日越大，年龄越小

第二趟分配、收集（按“月”递增）：



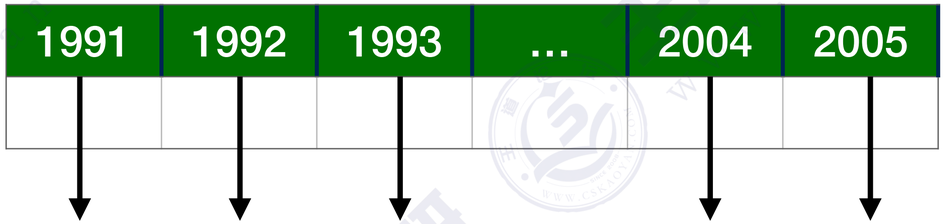
基数排序，时间复杂度 = $O(d(n+r))$

$\approx O(30000)$

若采用$O(n^2)$的排序，$\approx O(10^8)$

若采用$O(n\log_2 n)$的排序，$\approx O(140000)$

第三趟分配、收集（按“年”递增）：



基数排序的应用

某学校有 10000 学生，将学生信息按年龄递减排序

生日可拆分为三组关键字：年(1991~2005)、月(1~12)、日(1~31)

基数排序，时间复杂度 = O(d(n+r))
≈ O(30000)

若采用$O(n^2)$的排序，≈$O(10^8)$
若采用$O(n\log_2 n)$的排序，≈O(140000)

基数排序擅长解决的问题：

①数据元素的关键字可以方便地拆分为 d 组，且 d 较小

②每组关键字的取值范围不大，即 r 较小

③数据元素个数 n 较大

基数排序的应用

基数排序，时间复杂度 = O(d(n+r))

基数排序擅长解决的问题：

①数据元素的关键字可以方便地拆分为 d 组，且 d 较小

反例：给5个人的身份证号排序

②每组关键字的取值范围不大，即 r 较小

反例：给中文人名排序

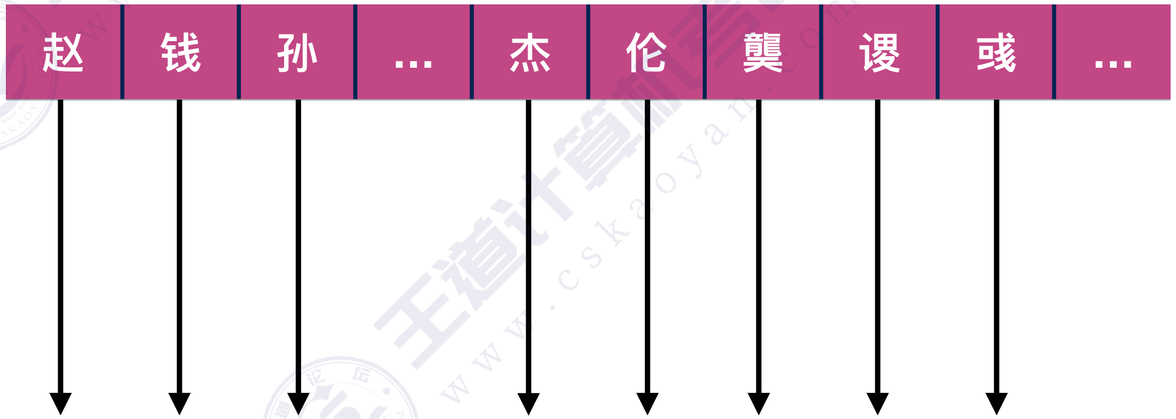
③数据元素个数 n 较大

擅长：给十亿人的身份证号排序

每个字可能有上万种取值

身份证号 XXXXXXXXXXXXXXXXXX

18位身份证号需要分配、回收18趟



知识回顾与重要考点

- 基数排序
  - 算法思想
    - 将整个关键字拆分为 d 位（或“组”）
    - 按照各个 关键字位 权重递增的次序（如：个、十、百），做 d 趟“分配”和“收集”，若当前处理的 关键字位 可能取得 r 个值，则需要建立 r 个队列
    - 分配：顺序扫描各个元素，根据当前处理的关键字位，将元素插入相应队列。一趟分配耗时O(n)
    - 收集：把各个队列中的结点依次出队并链接。一趟收集耗时O(r)
  - 性能
    - 空间复杂度 — O(r)
    - 时间复杂度 — O(d(n+r))
    - 稳定性 — 稳
  - 擅长处理
    - ①数据元素的关键字可以方便地拆分为 d 组，且 d 较小
    - ②每组关键字的取值范围不大，即 r 较小
    - ③数据元素个数 n 较大